AGROFORESTRY SYSTEM DESIGN FOR PERI-URBAN ENVIRONMENT. CASE STUDY FROM DZIVARESEKWA, ZIMBABWE

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Tiivistelmä □ Referat □ Abstract

Kaupunkien nopean kasvun vuoksi, peri-urbaanit ympäristöt ovat ruoantuotannollisesti yhä tärkeämmässä roolissa. Erityisesti kehitysmaiden suurten kaupunkien asukkaat kärsivät ruoan ja polttopuun liian vähäisestä saannista. Pelto-metsäviljelyn avulla kaupunkien läheisillä, peri-urbaaneilla, alueilla voitaisiin tuottaa kestävästi sekä ruokaa että polttoainetta. Viljelyjärjestelmien kehittämiseen ja analysointiin on olemassa erilaisia suosituksia ja ohjeita, mutta näiden soveltaminen on usein vaativaa sekä aikaa vievää varsinkin viljelijöille itselleen. Tämän tutkimuksen tavoitteena oli kehittää yksinkertainen ja helposti sovellettava pelto-metsäjärjestelmän suunnittelumalli yhdistämällä elementtejä jo olemassa olevista agroekosysteemien suunnittelu- ja kehitysmalleista. Työhön valittiin kolme sovellettavaa mallia julkaisuista: Altieri (1983); Agroecology – The scientific basis of alternative agriculture, Nair (1989); Agroforestry systems in the Tropics and Jaenicke et al. (1995); Towards a method to set priorities amongst species for tree improvement research – A case study from West Africa.

Tutkimus sisälsi kolme eri vaihetta: suunnittelumallin kehittely, testaus sekä analyysi. Mallin testaus toteutettiin Zimbabwen pääkaupungin Hararen peri-urbaanilla alueella Dzivaresekwassa. Pelto-metsäjärjestelmän suunnitteluun tarvittava aineiston keruu sisälsi kolme eri osiota: paikallisten viljelijöiden haastattelun, projektialueen analysoinnin sekä projektialueen viljelijöiden haastattelun. Näiden aineistonkeruumenetelmien perusteella valittiin lajit ja järjestelmän rakenne kyseisiin olosuhteisiin sopivaksi. Suunnittelumallin toteutus edellytti runsasta tiedon keruuta alueen viljelyolosuhteista. Suunnitteluprosessi vei aikaa noin neljä kuukautta, mikä voi olla liian pitkä aika monelle viljelystä elantonsa jo saavalle viljelijälle. Kuitenkin, jos kyseessä on täysin uuden viljelyjärjestelmän suunnittelu, vaadittava aika voidaan nähdä kohtuullisena. Suunnittelumalli on melko hyvin sovellettavissa aina kyseisiin tarpeisiin nähden. Mallin testaaminen kuitenkin osoitti, että kerätyn aineiston pohjalta mm. sopivimpien viljelylajien valitsemisprosessi vaatii edelleen kehittelyä.

Avainsanat □ Nyckelord □ Keywords

Peri-urbaaninen viljely, pelto-metsäviljely, agroekosysteemit, Zimbabwe, viljelyjärjestelmän suunnitelu ja - analysointi

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Tiivistelmä □ Referat □ Abstract

Along with rapid population growth, peri-urban environments have a great potential to improve urban food production. Especially, in developing countries people living in big cities are suffering from food and firewood shortages. Agroforestry could be a sustainable way to produce food and fuel in peri-urban areas, areas surrounding cities.

For the development and the analyzing an agroecosystems, various recommendations and guidelines are in place. However, applying these recommendations and guidelines can be complicated and time consuming. The aim of this study was to create an agroforestry system design model which would be simple and easy to use. The model was created based on already existing agroecosystem analyzing and design models. From which publications by Altieri (1983); Agroecology – The scientific basis of alternative agriculture, Nair (1989); Agroforestry systems in the Tropics and Jaenicke et al. (1995); Towards a method to set priorities amongst species for tree improvement research – A case study from West Africa, where chosen to be applied.

The study included three different stages: a development of the design model, testing the model and analyzing the model. The testing part was implemented in Dzivaresekwa, a peri-urban area of Harare, Zimbabwe. The data collection for design the agroforestry system consisted interviews of local farmers, project farm characterization and the interview of the project farm manager. Based on the data collected, suitable species and their arrangement were decided.

The application of the design model required comprehensive data collection about the project farm's farming possibilities. About four months was used for the whole design process. This might be too long for most of the farmers depending on agriculture as their only income. However, if the process is done for an entirely new farming system, the time can be found as reasonable. The model can be quite easily modified for each project in question. However, the testing of the model proved that some development should still be carried out. For example determining the suitable species should be simpler.

Avainsanat □ Nyckelord □ Keywords

Peri-urban agriculture, agroforestry, agroecosystems, Zimbabwe, agricultural system design and analysis

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Supervisor: Juha Helenius

PREFACE

This study was part of the Dzikwa Trust Fund Reforestation project in cooperation with The University of Helsinki/The tropical Resource Institute (VITRI), University of Bindura, Finnish Ministry of Foreign Affairs, Zimbabwe's Forest Commission and the City of Harare. Zimbabwe Aids Orphans Society was granted by Finnish Ministry of Foreign Affairs with a fund for reforestation project in Dzivaresekwa during 2011-2013. The grand was aimed to use for reforesting 90 hectares of land rented by the City of Harare.

As I experienced, working in Zimbabwe is not very easy without good contacts. Therefore, I want to express my greatest thanks to Oili and Seppo who were in a key role for the vital contacts in Zimbabwe. Without you I would not have collected the data needed for the study. I also want to thank all the support from Dzikwa Trust students and employees. Especially, I want to thank Takawira Kindoni who worked as my interpreter in the interviews of the local farmers as well as Marvellous Nyoka and Lloyd Chigada who were helping me with the agroecological survey of the project farm. I also want to express my gratitude to Mr. Mhakayakora for all his help.

During the data collection and back in Finland, I got priceless help from D. Sc. Eshetu Yirdaw, PhD Mike Starr and Prof.emer. Olavi Luukkanen. With GIS-formulating I would not have survived without PhD Eduardo Maeda and for the linguistic help I am most thankful to Kaisa Karttunen. I want to express my greatest thanks to you all.

I wish to thank all co-operators from Bindura University, University of Harare, Cosmo Trust Chair, Zimbabwe Forestry Commission and World Agroforestry Centre (ICRAF) as well.

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Maria Suomela

CONTENTS

LIST OF ACRONYMS AND ABBREVIATIONS

DR & SS	Department of Research and Specialist Service (Ministry of Agriculture, Mechanisation and Irrigation Development of Zimbabwe)
FAO	Food and Agricultural Organization of the United Nations
ICRAF	World Agroforestry Center (International Council for Research in Agroforestry)
MPT	Multipurpose tree species
SSA	Sub-Saharan Africa
UN	United Nations
USDA	United States Department of Agriculture
WFP	World Food Programme
WHO	World Health Organization

1 INTRODUCTION

Agricultural development is usually centralized to rural areas where it is usually the main source of livelihood. Many times agriculture is a secondary livelihood for urban people, but in developing countries, agriculture is an important source of income in urban areas as well. During the last decades, one of the global trends has been rapid urbanization followed by continuing crisis of poverty, food shortages and increasing number of contamination of diseases like HIV/AIDS. In a case of SSA, this has been explained to be caused by complex interactions of agroecological, social, economic and political variables (Kwesiga et al 2003). These have awaked the interests of green urbanization and peri-urban agriculture within different actors. Agricultural development close to the settlements could be one way to alleviate some of the problems. Besides food production, agriculture can respond to other needs like fuel or medical demands as well. Agroforestry is potential concept for urban areas to fulfill these other necessaries. For creating a successive agroecosystem a thorough system design is in key role. Various system design guidelines have been established but recommendations focusing on urban agriculture from farmer's point of view are still few.

1.1 Agroforestry

Agroforestry is an old cultivation habit where trees and crops are growing in the same field. More specific description by ICRAF (1997) includes parts such a: planted crops and woody components and possibly animals with dynamic, ecologically based natural interaction are involved in the agricultural system which provides diverse, sustainable production with increased social, economic and environmental benefits. This and plenty of other descriptions for agroforestry show that there is a strong belief that agroforestry is a good option for common agriculture. Many studies, most of them relating to small farmers in tropical countries have confirmed this belief (Tougiani et al. 2008, Sanchez et al. 1997, Ajayi et al 2009, Magcale-Macandog et al. 2010, Panday 2007).

Many times trees are underused or unrecognized in agricultural sites. Some of the benefits from adding trees to agroecosystem are that they increases the total production, give more diverse products and improve soil characteristics, control erosion, maintain the soil fertility to mention few. Furthermore, large tree canopies affect solar radiation, precipitation and air movement as in the same time the root system influences to the soil processes (Farrell 1990). These impacts are not always positive, but with the right choice of species suitable to the environment, trees have the potential to improve the agricultural production. In this sense, agroforestry can be found as a good option to many environments.

Three main types have been identified from the many different ways that agroforestry can be practiced; agrosilviculture, in which trees and crops are combined together; silvopastoral system, in which trees are combined with animals; and agrosilvopastoral system in which all three components are managed together (Gliessman 2007, Nair 1989). For well-functioning agroforestry system, the understanding of the interaction between species is essential. For example, impacts of trees to other plants in the system can be either positive or negative or something in the between of these. Competition or allelopathic interference with other plants, microclimate conditions which favors diseases and pests or mechanical damage by falling fruits or branches, can be noticed to be negative effects. The best way to avoid these impacts is often by appropriate tree and crop species selection, well considered spatial arrangement of the trees, right planting time and good management of trees (Gliessman 2007). With right choices and careful management of the system, the negative influences can be turned over as positive. For example microclimate created by trees can be favoring the under growing crops when moisture gets higher and intensive sun shine gets lower. In Latin-America this has been proved many times in coffee plantations (Lin 2006, Siles et al. 2009). Agroforestry usually increases the biodiversity of the area in a way that weeds, pests and diseases can be controlled easier. When the number of species in the field increases, more pernicious organisms might be introduced as well. However, when the biodiversity is high enough, the species are controlling each other in a way that none of them get too high in number to cause damage to all species (Bengtsson et al. 2005).

Changes in soil functionality when introducing trees into the system have been studied relatively much. The theory behind these researches is that trees may affect the nutrient status of the soil by using the minerals deeper in the ground and return the leached nutrients and deposits back to the surface through leaf litter. When the amount of organic matter increases in the shape of humus, soil's cation exchange usually stabilizes and extreme soil reactions decrease. This improves the availability of essential nutrients as nitrogen, phosphorus and sulfur are mainly occurring in organic form. High amounts of organic matter improve the availability of these nutrients (Farrell 1990). Farrell (1990) has illustrated these impacts with *Prunus capuli* and *Juniperus deppaena* by measuring the surface soil properties with respect of the distance from the trees. The highest values were found under *Prunus capuli* canopy.

The arrangement of trees can be implemented several different ways depending on the farmer's needs and the environmental conditions. In silvopastoral systems, targeting to harvestable products from trees, use of living fence or wind breaks or boundary planting is usual. In this system trees are planted around the cultivation plot, which helps the harvesting from both, trees and crops as well as gives a protection to crops growing in the middle (figure 1) (Gliessman 2007).

In sites where wind is the main problem and crop production the main target, shelterbelts are commonly used. In this arrangement, trees are planted in rows with high density, against the usual direction of wind (Gliessman 2007).

If trees are planted with the intention to provide mulch from leaf fall or pruning, it is common to plant trees in narrow rows between the alleys used for crops. This arrangement is called alley cropping (Gliessman 2007). This system is also popular to use when fruit trees are planted with vegetables (figure 1). The system allows light to get through for the vegetable as in the same time trees are maintaining the soil fertility. Fruits from trees are also easy to collect with the alley cropping system.

With the cases of poor soil conditions where permanent cropping system is not feasible, a rotational design can be useful. In this kind of arrangement, the successional time during tree development is determined by for example the length of fallow needed in shifting cultivation. This is a good way to make sure that the soil is not overused and can be maintained in use of agriculture (Gliessman 2007).

Trees with agricultural value can be planted dispersed amongst the cropping system (figure 1). In this kind of an arrangement, it is important that tree species used do not have very dense canopy or allopathic impacts (Gliessman 2007).

Homegardens are classic examples of agroforestry in tropical lands. However, the definition is used rather loosely. The system can be understood as almost everything between growing vegetables behind a house to a complex multilayered system in contact with the house (Nair 1989). The typical characteristics of these systems are high species diversity and great complexity in small area. The size of a homegarden usually varies between <0.5 and 2.0 ha (Gliessman 2007). Because of this, homegardens are usually found in areas with high population density. The land use is efficient as many plant layers are found. Woody perennials are common to dominate homegardens as they create the topmost layer of the system. Usually, below trees are growth mixtures of annuals and perennials in different heights, producing wide variation of food and other products. The structure has been said to be similar to tropical forests (Altieri 1987, Gliessman 2007). The most studied homegardens are in South-East Asia and Latin-America, but the structure is commonly used in Africa as well. In Asian homegardens trees like *Mangifera indiga, Moringa sp.* and *Sesbania gradiflora* are common, and in West Africa indigenous trees producing leafy vegetables, fruits or spices for example *Pterocarpus spp., Dacroydes edulis, Petaclethra macrophylla* are frequently found (Nair 1989). Agroforestry systems present one kind of agroecosystem in which biodiversity is usually higher than in common agroecosystems. As stated by Thrupp (1998), evidence has showed that integrating agriculture and biodiversity is beneficial for food production, ecosystem health as well as economically and ecologically sustainable growth.

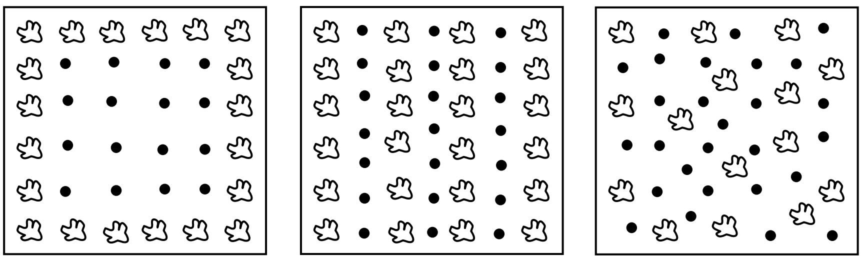

Figure 1. Examples of tree and crop arrangement (alley cropping, boundary planting and mixture)(modified from Gliessman 2007) (♧ =tree, •=crop)

BOX 1.

Agroforestry in Zimbabwe

It can be assumed, that in Zimbabwe agroforestry has been practiced centuries like in many parts of the world. Only the name for the practice, agroforestry, has been found as relatively new. The documentation of agriculture and tree uses in Zimbabwe before 1980's is very rare. It is known that that the main focus in rural development before the independence (1980) was in crops and livestock. The forestry server was concentrating on softwood plantations and native woodlands on state land (Campbell et al. 1991). Farmers were even encouraged to remove trees from arable lands by extension officers. After the independence, the interest forward trees in communal lands increased again. Even agroforestry courses were held by foresters employed by agricultural extension service. The first agroforestry research was established in 1986 (Campbell et all. 1991).

1.2 Agroecosystems

Agroecosystem is a human created ecological system which is functioned by natural processes as well as by human inputs. Agroecosystem is a term used for describing agricultural activities and interactions between the systems components; people, environment and other organisms. It can be used as a synonym to farming system or agricultural system. It can also be put under the broader context of food systems including agricultural production, use of resources, product processing and marketing within an agricultural region and/or country (Altieri 1987). Agroecosystems are open systems receiving inputs from outside and producing outputs that can enter external complexes like groundwater, vegetation, cities and the like. Many kinds of agroecosystems can be recognized depending on methods used; the intensity of expenditure of capital and labour, resulting output of products, the use of products or the structure of the system. Agricultural characteristics like soil fertility, crop yield, environmental degradation and so forth, are part of the agroecosystem impacted by other complex factors such as: micro-organisms, nutrient content or water balance (Altieri 1987, Kwesiga et al. 2003). In general, agroecosystems are the base for all agricultural production and the understanding of their functioning is the starting point for further development.

In this study the main definition for agroecosystems, supported with the ones mentioned above is that: agroecosystem is productive entity where different organic and inorganic components are interacting with each other and creating this way a functioning ecological scheme.

1.3 Existing agroecosystem analysis

For establishing a beneficial agroecosystem, it is essential to understand the system components and have proper planning process. There are plenty of different kinds of agroecosystem designing and analyzing methods published; RRA (Rapid Rural Appraisal) and FSR (Farming System Research) being widely known examples. These procedures are conceived for analyzing the farm sustainability in the light of social wellbeing of farmers. Gordon R. Conway and Diana Carney are examples of researchers who have been working with sustainable farming system analysis. Their studies have been followed by others, such as Pretty (2000) and Scoones (1998). Conway (1985) has presented for example a three step approach for building a sustainable agroecosystem and later Scoones (1998) has released a framework for analyzing sustainable rural livelihoods referring to Conway (1985 and Chambers and Conway 1992) and Carney (1998). Pretty (2000) in turn, has referred Carney (1998) and Conway (1991) in his asset-based model for agricultural system analysis. In addition to these, many other frameworks have been proposed for agroecosystem analysis and designs as well.

Many of the agroecosystem analysis and design methods are related to the general system theories. Basis for these theories is in the presumption that different component (objects and attributes) are interacting in some particular system which has to be recognized. This complex system creates the base of all functions. The better the system is understood the better its functionality can be improved (University of Twente 2013, Lazlo and Krippner 1998).

1.4 Urbanization

Rapid urbanization has been part of the development of many countries all over the world. Especially, in developing countries people are moving closer to urban areas hoping to get more income. Agriculture is still the main livelihood in these countries as approximately 80 % of rural people are counting on it (FAO 2007). However, in many cases agriculture is not profitable income enough, so people are moving to cities in search for better jobs and working part time in agriculture (FAO 2007).

The UN-Habitat (2006) has reported estimation where the percentage of urban residents in SSA would increase from 30 to 47 percent of the total population during years of 2005 to 2030. In many cases, the urban population growth is increasing the number of the urban poor as well (Kutiwa et al. 2010). Food demand gets higher and so do the prices with decreasing access to food. These negative causes of urbanization occur mostly in developing countries. In 2001 there were 187 million slum dwellers in Africa (20%) and these people are the most vulnerable to food security (FAO 2007). In this study food security is defined as "access to food for a healthy life by all people at all times". Food security is one of the major concerns in many developing countries in urban areas. The other is related to the environmental problems and overuse of natural resources like wood. Many urban people in developing countries still rely on wood as their household energy source (Furukawa et al. 2011, Davenport et al. 2011). As Nfotabong-Atheull et al. (2011) and Abbot and Homewood (1999) have presented in their studies, the over use of trees for fuelwood in urban areas has caused degradation to environment. Tropical vegetation can many times be found as sensitive for intensive management and rapid unnatural disturbances. This is one of the characteristic which has set the need for more sustainable agricultural practices in tropical urban areas (Nfotabong-Atheull et al. 2001, Abbot & Homewood 1999).

BOX 2.

Urbanization and food supply in Zimbabwe

Along with other SSA countries, Zimbabwe's urbanization has been rapid during the last decades. The urban population in Zimbabwe increased 7 percent from 1982 to 1990 (Kajumulo Tibaijuka 2005). The amount of urban population in Zimbabwe was around 4 930 million in 2011-2012 (The World Bank 2013). Of that, some 60-70 % lives in the two biggest cities: Harare the capital and Bulawayo (Gumbo 2000). The number of urban population is estimated to be around 8 930 million until 2020 (FAO 2001). The country can be included into UN-Habitat estimation with the urbanization rate of 38 percent in total (2010) (CIA 2012, UNICEF, 2012).

In Harare, the population growth rate slowed down in 1990's. This was caused by the combined impacts of structural chances, rising unemployment, housing shortages, out-migration and the HIV and AIDS epidemic. After 2000 the country ran into political and economical crises, which kept the urbanization rate lightly growing. Today Harare's population is estimated to be around 1.8 to 2 million (Tawodzera et al. 2012). This kind of development has created challenges for the country, especially in the case of food security. Zimbabwe has been under a high level of inflation, unemployment, growing poverty, volatile political atmosphere and a weak currency, which has resulted in mounting prices in cost of living after the year of 2000 (Tawodzera et al. 2012). The food production index collapsed from 107.9 to 89.4 between 2001 and 2002 (The World Bank 2013). In this sense, the insecurity during the last two decades has set the challenge of assure decent food supply and decrease of urban poverty even more efficiently than before. Slowly, the country has started to recover from its crises. However, the unemployment rate in 2008 was still estimated to vary between 50 to 94 per cent (ILO 2009, UNECA 2010); from which major part was concerning the youth (aged 15-24). In 2008, Zimbabwe's GDP grew up to 12.6 percent. This was recorded as the highest over a decade (UNECA 2010).

Some studies about urban food security in Zimbabwe have been conducted. Tawodzera et al. (2012) have given an example of two studies in 2003 where Harare's food security varied between 20 to 64 per cent depending on the measurement methodologies. In this sense, it is hard to say what the real situation is. FAO, WHO and WFP have stated that the percentage of food insecurity in Zimbabwe would be around 30 % and in Harare only 13% (FAO 2010). Even the proportion of urban people in Zimbabwe is high, the role of agriculture is still important in the sense of food security. Approximately 7 million people in Zimbabwe are counted as agricultural population who are improving their food supply by cultivation (FAO 2010).

Zimbabwe's seasonal calendar in agricultural perspective combined with critical events timeline describes the main agricultural practices and their timing (figure 2). It also shows the critical times for food supply. It is clear, that the hungry season is at the same time with rainy season when the harvesting is low. The main problem for critical times lays in storing which is found challenging in many parts of the country. The other factor is poverty, which is the most problematic in poor townships and in rural areas where food security and — supply is also low.

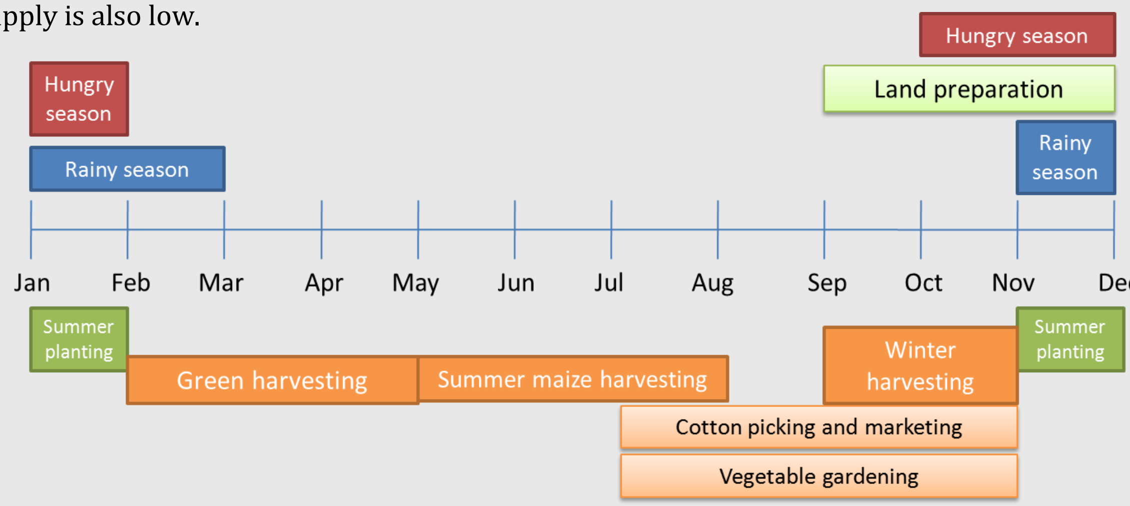

Figure 2. Zimbabwe's seasonal calendar for agricultural practices and hungry seasons (USAID 2012 modified)

1.5 The concept of peri-urban agriculture

Due to the population growth in urban areas, the cities have expanded into formerly rural areas, which are now called peri-urban areas. This term refers to urban peripheries which have gone through notable changes during the last decades (FAO 2007). The population density has increased fast and constructional changes have been many. People in peri-urban areas are usually from both rural and urban backgrounds. In rural areas most of the households are self-sufficient in food because of their own agricultural production (Kutiwa et al. 2010). In the cities, the situation is different because food security is dependent mostly on markets. Peri-urban areas have become extremely important option for big cities to enhance food supply to meet the employment and nutritional needs of the citizens (Mbiba 1999). However, dramatic and rapid changes in population densities have set challenges to environment as well. Nature in and around the urban areas is usually under the pressure of deforestation, soil degradation, toxics, biodiversity loose, loading of waist among many (FAO 2007). Natural resources are more needed and wasted and the sustainability in production can be disputed.

BOX 3.

Urban and peri-urban agriculture in Zimbabwe

There are mainly two ways to produce food in the city: the urban gardens (private) and public open spaces (property of the city). In Harare the public areas are usually spaces around buildings, community lands, parks, road sites, wetlands or steep slopes; areas that are unsuitable for houses or places waiting for another use (Gumbo 2000). Most of the cultivations are found from these public areas close to the high density housing sites, but not suitable for building. The plot size is usually very small ranging from 14 m^2 to 25 m^2 (Gumbo 2000)

The government does not support the “illegal” farming in the city’s areas as it is not in the urban planning and management plans (Gumbo 2000). However, there are policies that allow urban-agriculture; people can form groups for applying a permission to cultivate in a designed land. The process is long and complex which has not encouraged residents to take part in it (Gumbo 2000).

Ngwerume and Mvere (2003) found out in their study from Zimbabwe’s urban and peri-urban areas, that most important traditional vegetable crops for producers and traders were pumpkin leaves (*Curcubita moschata*), okra (*Abelmoschus esculentus*), tsunga (*Brassica juncea*), spiderplant (*Cleome gynandra*) and cowpea (*Vigna anguiculata).* However, other than traditional plants were the most important for marketing. This included vegetables like kale; rugare viscose (*tronchuda portuguesa var.)* which was found most commonly (Ngwerume and Mvere, 2003). According to Gumbo (2000) most common plants cultivated in Harare were leafy vegetables from which rape and tomatoes were most popular. Plants cultivated outside the households area were commonly maize, beans and sweetpotatoes.

Commonly, urban agriculture aims to produce plenty of food with good market opportunities. Maize is a good example of this kind of production as it is a major crop produced in many SSA urban areas. In the study by Afrane et al (2004) located in Ghana, maize was almost always found from the urban cultivations close to big cities like Kumasi. Another example is from the mid-1990s, when rain-fed maize in and around Harare was valued at $25 million and covering more than 9,000 hectare (UN-Habitat 2006). The negative sides of these kinds of monoculture cultivations are a risk of malnutrition within people and degradation for environment as the plant diversity becomes low.

2 AIMS OF THE STUDY

The aim of the study was to gain more understanding about designing an agroforestry system in peri-urban context. It was also an intention to propose a simple guideline for design such a system.

At the case study level, a practical aim was to propose solution for an agroforestry system for a farm in Harare, Zimbabwe.

The study is wished to be useful as a background for further urban and peri-urban agricultural development. In the local level the research can act as a pilot project for the areas' agricultural improvement.

3 THEORY APPLIED FOR THE SYSTEM DESIGN

Many agroecosystem analyzing and designing methods used for similar purposes have been published. In this study three of these were chosen as a base for new design model. The selection was done by estimating the suitability of the methods for the particular research. Time and resources were main limitations for wider exploration. In the other hand, many of the existing frames are suggesting deep social analyses which were not found relevant for this study. Based on these arguments Altieri's (1983), Nair's (1989), and Jaenicke et al.'s (1994) guidelines were chosen.

Altieri (1983) - Agroecology – The scientific basis of alternative agriculture

The purpose of Altieri's book is to provide simple synthesis of the research on novel agroecosystems, and technologies and an analysis of ecologically based farms, for establishing the basis of alternative agriculture. By alternative agriculture he means farming that attempts to provide sustained yields through the use of ecologically sound management technologies.

The chosen studies present agroecosystem analysing and designing at different levels, from which Altieri (1983) focuses in the base of the system and its components. He has presented an analyse method starting from selection of the target farm, moving forward to description of the environment, and finally doing field surveys about biophysical and socio-economic factors. He has underlined the importance of conceptualizing the agricultural system as in many other system theories asking: What is the purpose of the system; boundaries, context, components, interactions, inputs and so on. Altieri's purpose for the guideline is to enhance the understanding and underline the importance of natural entities for designing a sustainable agricultural system. The practise starts from discovering the natural vegetation, primary production, which sets the base for agricultural possibilities. According to Altieri, a critical part of agroecological design is soil characters which tell about the land use capability. In his guideline he uses the soil classification by USDA (1959) in which the soils have been classified into eight land use capability groups by physiochemical factors.

Altieri presents in his guideline the need for economic survey which should explain the financial aspects and viability of the farming system. This checklist includes features from land, labour and capital. Detailed description of farm management practices is also presented as a part of the recommendations. This covers data about land preparations, weeding, thinning, harvesting and other practices done in the target field.

Nair (1989) - Agroforestry systems in the Tropics

Nair presents in his book "Agroforestry systems in Tropics" an ICRAF's Agroforestry System Inventory project. The idea for the inventory is to increase the understanding about agroforestry systems. Furthermore, there is five more detailed objectives mentioned: to record the functioning of different agroforestry systems; to evaluate the existing systems; to identify the methods to improve the systems; to update the statistics and trends in agroforestry; and to disseminate quantitative and descriptive data about agroforestry for the use of researchers and development workers. So to conclude the aims of Nair's study is to get general idea of the present agroforestry systems.

For the data collection, Nair underlines the background knowledge of the farmland studied and its surrounding environment, as essential for further agricultural development. This is the first part of the questionnaire in ICRAF's data collection format. It includes descriptive background information of dominant agroforestry systems and practices as well as geographic, biophysical and climatic descriptions, and land use information from the existing agroforestry farms. The second part is focused on agroforestry farm’s dynamics, structure, performance, socio-economic features and other characteristics of the system. Soil characteristics, topography, farm size, number of employees, demographic factors and arrangement of the components are just some examples of the questions in the second part. The third part is for evaluating the system. The idea in this part is to see how the agroforestry farm develops and keeps on functioning after some years. Questions concerning for example the system’s weaknesses; is there a need for rearrangement or further research, are tried to be answered. ICRAF’s format is very detailed and it includes parts that may not be suitable for conventional farms. For example, agroforestry keywords or plant functions may be hard to recognize from all farming systems. However, there is a note that all data posed may not been needed for the study to overview the systems.

Jaenicke et al. (1995) - Towards a method to set priorities amongst species for tree improvement research – A case study from West Africa

Jaenicke, Franzen and Boland have focused their study to agricultural tree improvement. The study was based on tropical multipurpose tree species (MPT’s) with valuable products to world commerce. The research was related to ICRAF’s tree improvement activities where indigenous MPT-species are identified for more efficient utilization.

The study was based in the region of Humid Lowlands of West-Africa (HULWA). The idea was to recognize the most important agroforestry products or services and MPT species potential to be provided. The end product should have resulted in a remarkable economic and environmental impact to many farmers and the whole region. Four key selection categories were used for recognizing the species: Farmer interest to the species; management and growing characteristics of the species; product types for evaluating its suitability for given end-use and market; and research considerations for tree improvement for each species. The ideal species would have produced an MPT-product of best value for the community; suited the chosen agroforestry technologies; had the potential to large gains from tree improvement research; and had good adoption potential among farmers. The study argued that there is a need to develop a rational method for setting priorities amongst species for improvement research. This should be seen as a part of a larger effort to integrate farmers' opinions and needs with researchers' considerations as a basis for planning the research.

Jaenicke et al.'s research started with realizing the background information of the region with the help of experts. This data was used for creating an idea of the regions farmers' priorities and possibilities: fruits, fodder, soil fertility, medicines and so on. Based on this data, the scoring model was decided to determine the most appropriate species. Different criteria were converted into value where for example "adaptability to non-acid soils" received a low number because non-acid soils are not common in the region. In total 22 criteria were screened for fruit and food species, 10 species for poles and stakes and 15 species for soil improvement. The highest scores were given for species like *Irvingia gabonensis* (fruits and food), *Cassia spectabilis* and *C. simea* (poles and stakes) and *Flemingia macrophylla* (soil improvement).

4 METHODS

4.1 Formation of the design model

4.1.1. General description of the process

Forming the design model was done by applying the existing guidelines and to fit them into the local conditions and the study aims. Figure 3 presents the simplified process of the final design.

There were five main aspects impacting to the final design. The process began from the theory which gives the base for the design frame. The next step was to apply the theory into the study; to recognize the limitations and the possibilities and the study aim. Questions like: which parts can be applied and which are left out; what is relevant for achieving the aim, were to be answered.

The third step was already approved in the study area or through background studies depending on the previous data available. However, the idea was to define the main features presented in the theory in relation to the study area. Through this, the general characteristics of the project farm environment could be recognized.

The next part was to describe the possibilities of the farm for the agroforestry system. This included the farmer's (or farm manager's) interview for figuring out their objectives, input possibilities and other desires.

The final part was to combine all the data collected and identify the farming possibilities. The final species selection and arrangement was limited to suitable agroforestry species and local environmental possibilities as well as farmer's desires based on the data collected.

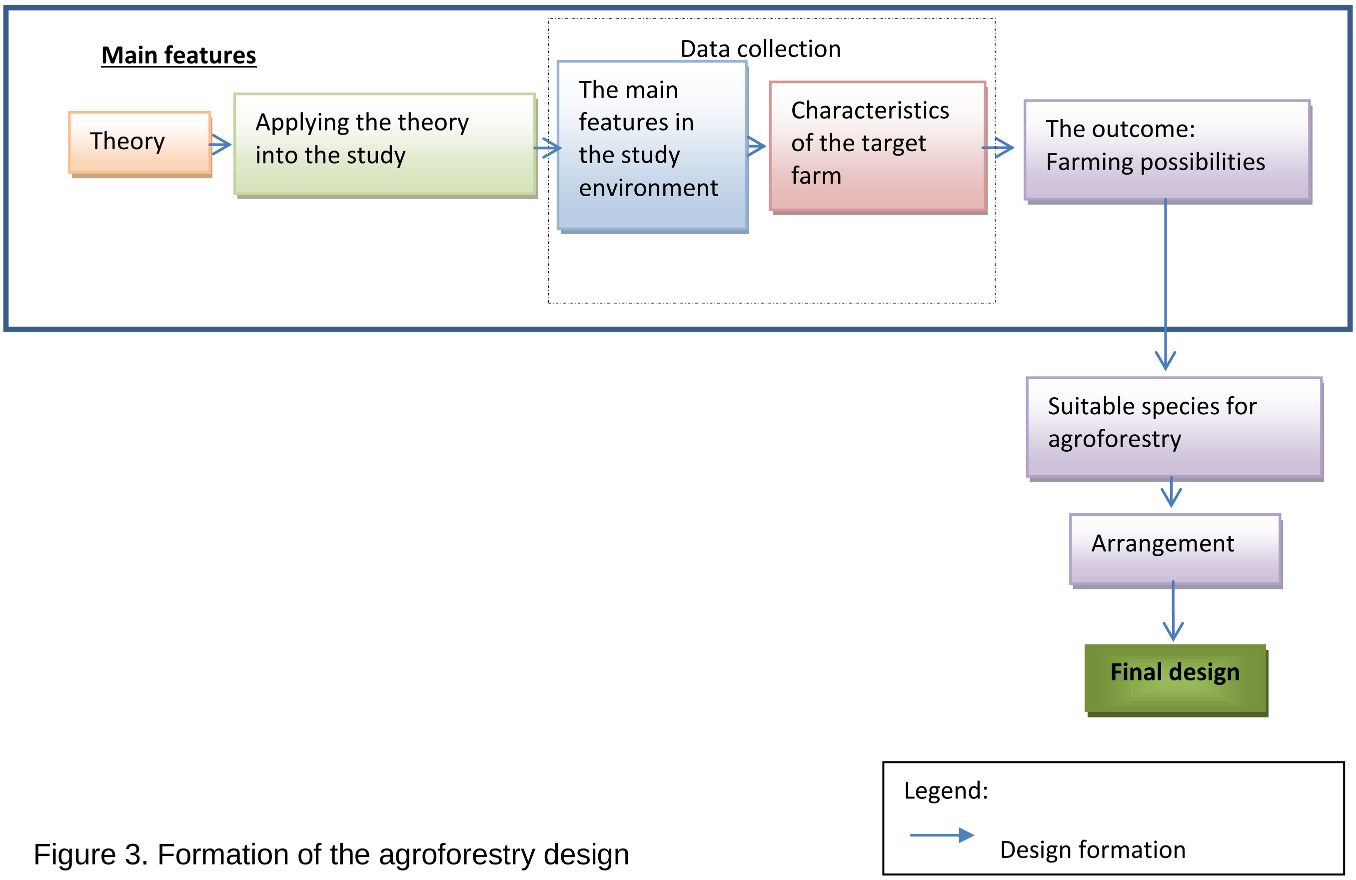

Figure 3. Formation of the agroforestry design

The idea is to create a frame that could be easy to modify into different cases. This was enabled by the design process moving from general to more focused case study. During this kind of a process, parts of the data collection and results can been dropped out if those are not found relevant for the case. However, the data collected should answer questions like: What are the main cultivation characteristics of the local environment? How does the target farm compensate with the surrounding environment? And, which of the results can be applied for the target farm?

4.1.2. Application of the design model to the case study

For this study the theory was taken from three existing guidelines: Altieri (1983), Nair (1989) and Jaenicke et al. (1995). Based on Altieri’s (1983) and Nair’s (1989) guidelines, the main features were selected to be ecological and social features of the study environment. More detailed elements were followed by all three guidelines.

Altieri’s (1983) guideline is a good base for all agroecosystem designs. In addition, of the Altieri's overall idea; “to see an agroecosystem as a part of natural functions”, some of his practical recommendations were applied to this study. Natural and primary productions were included by examining the native species in the existing farmland. This has been mentioned in Nair's (1989) guideline as well as a part of background information. As the study was carried out in the urban area of Harare, it was assumed that the most general descriptions of the farms (country, vegetation type, mean annual temperature, precipitation etc.) were equal.

Physiochemical factors like slope, water availability, basic nutrient content and pH were chosen to be determined in this study. These are mentioned in general in Altieri's (1983) guideline and more detailed in Nair's (1989) book. The basic nutrient content was primary macronutrients: nitrogen, phosphorus and potassium, as these nutrients are commonly most limiting factors in agricultural production (controls a process of growth, functioning etc.), and usually determined in agroecosystem analysis because of that. These nutrients are also consumed most by plants (> 10 kg/ha) (Brady 1984). Secondary macronutrients, calcium and magnesium which agricultural plants usually take < 10kg/ha, were also chosen because these two macronutrients are usually part of this kind of basic agricultural soil analysis (Brady 1984, Viljavuuspalvelu 2008). The other parameters, pH-levels and texture tell about the soil’s current fertility and functioning (Brady 1984, Viljavuuspalvelu 2008). PH-levels have strong effects on plant growth as its own, but the main impact comes through inorganic ions availability in different pH levels. In Jaenicke et al.’s research one of the criteria was related to soil acidity, so based on this pH was also natural choice for the study.

The need for socioeconomic studies was underlined in all three guidelines. These characteristics were to be measured mainly in the local farmers’ questionnaire or in the interview of the farm managers. For example, questions about labour intensity and cultivation target were included based on Nair’s and Jaenicke et al.’s recommendation. Part of the questions were left out or modified mainly because of their unsuitability or sensitivity (for example land ownership or capital details).

One part of Nair's guideline is the evaluation of the system. This was left out because implementation of the design was unsure and the time for the study was not long enough for evaluation. Furthermore, Altieri have presented the need of description of farm management practises as part of the new design process, but for this study these details were not found essential because the project farm did not have any regulated cultivation. Jaenicke et al.’s guideline was used most in the data analysis process as their research offers important notes to be considered when choosing the species. Species growing characteristics, water and nutrient needs, and multipurpose values were for example included in the species selection part.

The application of the design model to the study is presented in the figure 4. The detailed list of the research variables are presented in Appendix (annex 1), under the headings of the local farmer’s questionnaire, the agroecological characters of the project farm and the interview of the project farm managers’.

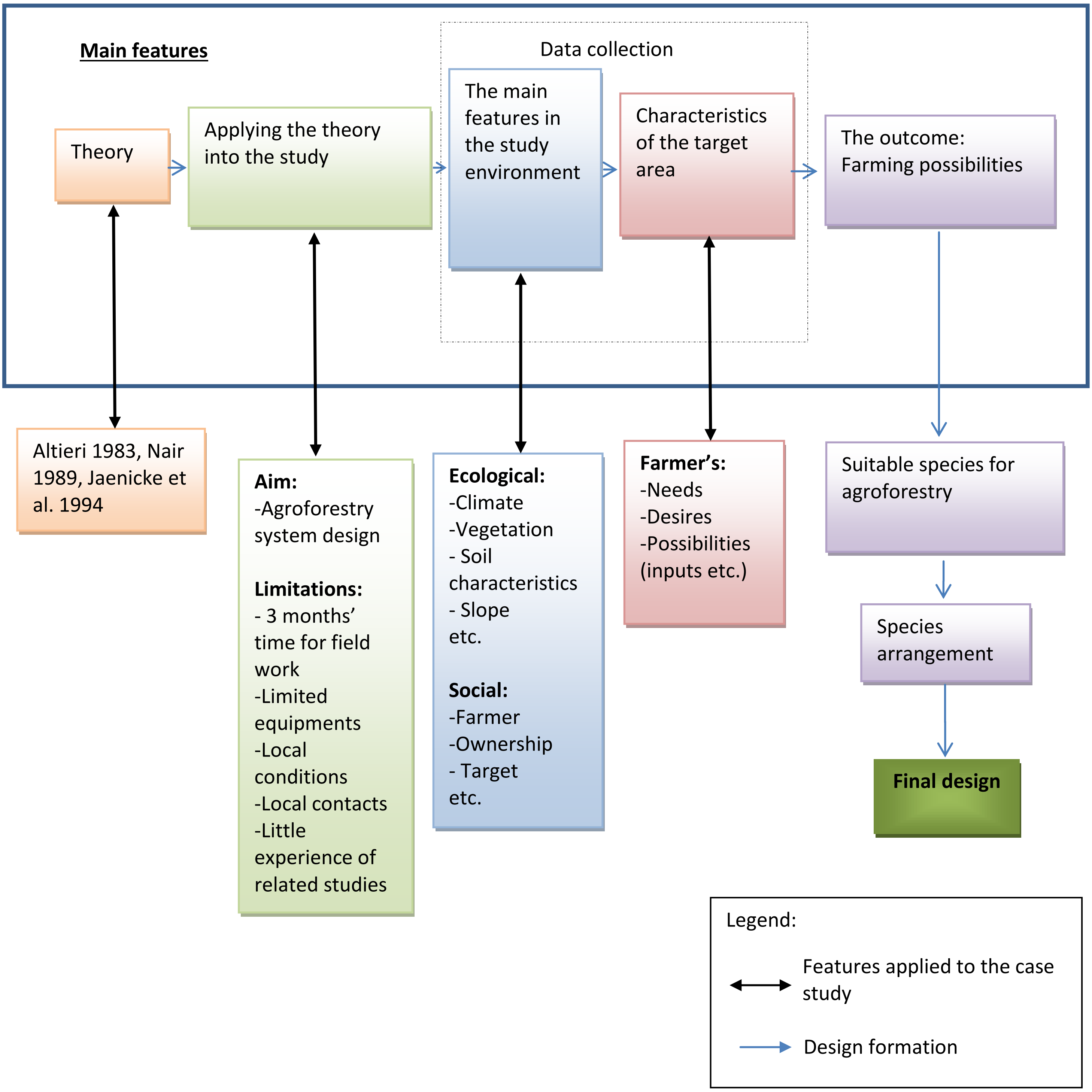

Figure 4. Formation of the agroforestry design applied to the case study

5 CASE STUDY

5.1 Materials

5.1.1 Study area

Figure 5. The map of Harare, in which Dzivaresekwa district have been pointed out (Google maps 2012).

Figure 6. The map of Zimbabwe and neighboring countries (CIA World Factbook 2012)

Harare, previously known as Salisbury, is the capital city of Zimbabwe, located in northeaster part of the country. Harare as a whole (known as greater Harare) covers around 900 km^2. This includes industrial areas as well, such as Harare North, Epwroth and others (The Herald 2012, Parlament of Zimbabwe 2006). The official language is English and commonly used local languages are Shona and Sindebele (the language of the Ndebele).

Harare is characterized with annual precipitation between 725-974 mm/year and average temperature of 15.5-20 °C (FAO 2012). According to Köppen–Geiger Climate Classification the predominant climate is called subtropical highland (Kottek et al. 2006). Harare city is located in one of the highest parts of Zimbabwe at an elevation of 1500-2000 meters above sea level (Mbiba 1999). This affects the climate in a way that temperatures are rather low for tropical lands. The general vegetation type is tropical dry forest (FAO 2001). According to agroecological zoning in Zimbabwe, the city is built on agricultural soils, Natural region of 2a, which is categorized as intensive farming area for crop and animal production (Ngwerume and Mvere 2003).

Dzivaresekwa (also known as Dzivarasekwa) is suburb in western Harare. It is located 16 km south west from Harare centrum. It is one of the poorest townships in Harare with high population density. It is estimated to inhabit about 156 000 people. The area started as a town management plan for domestic, low income workers. Today Dzivaresekwa covers 3 distinct areas with people from different social classes: Dziwarasekwa 1-4, Tynwald south and Kuwadzana phase 3 (Muringayi 2012). Based on construction time Dzivaresekwa contains 7 different areas (figure 7). The first was Dzivaresekwa 1 which was built around 1950 -1960. It extended with the areas of Dzivaresekwa 2 to 4, Tynwald south, Kuwadzana phase 3 and Dzivaresekwa extension which was established in the beginning of 1990. Vegetation in Dzivaresekwa is characterized by wooded grassland (canopy cover 20-80%, height 1-5m) or cultivated land (Forestry Commission of Zimbabwe 1996).

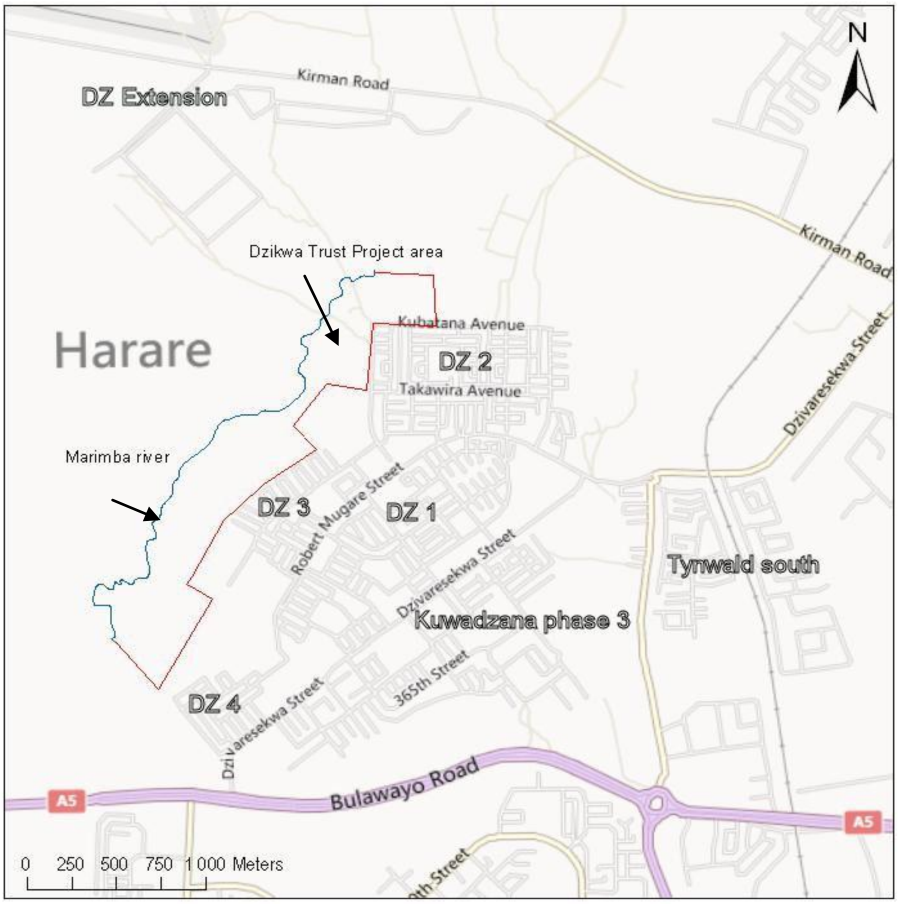

Figure 7. Map of Dzivaresekwa with the project area
(basemap from ArcGis - ArcMAp version 10)

Zimbabwe Aids Orphans Society is a Finnish society working for poor Zimbabwean orphans in Dzivaresekwa. Their core principle is to support local children for receiving basic education (Zim-orvot 2013). In 2010 the society was given a grant for reforestation project in Dzivaresekwa by Finnish Ministry for Foreign Affairs. The project aim is to restore 90 hectare waist land area for community benefits. The plan has been to work on firewood production, erosion control, soil improvement and water and biodiversity conservation and offering environmental education and working opportunities for locals. Establishing an agroforestry system is one of the main objectives which will be supported by this study. Tree planting has begun started already in 2008 (*Eucalyptus grandis*) and it has been continual. The project farm area includes also a tree nursery and bee cultivation maintained by a local forester.

The Dzikwa project farm is located in the western part of Dzivaresekwa. The project farm has been used for unregulated maize cultivation and as a waste dump site. In 1970's the first eucalyptus plantations in the project farm area was established. Before this the area was probably covered by natural forest type called *Miombo*. In 2004 trees were cleared for firewood and timber by community members (Lukkanen 2012, Mupfigo 2012).

5.1.2 Characteristics of Miombo woodland

Miombo woodland is the most common savanna vegetation type in Africa's southern hemisphere (Campbell 1996). It covers about 2.7 million km^2 (Campbell et al 1996, Munishi et all. 2010). The name comes from the dominating tree genus *Brachystegia* (Miombo in Swahili and many other Bantu languages) which can be found in 21 different species. The other dominating genera are *Julbernardia* and *Isoberlinia*, all three belonging to legume family; Fabaceae, subfamily Caesalpinioideae (Cambell et al 1996.). Altogether, Miombo woodland is also known as Brachystegia woodland or Brachystegia-Julbernardia woodland (Niemelä 2011).

Miombo use to cover a major part from the southern Africa from Angola and northern-Namibia to southern part of Democratic republic of Congo and further on all the way to Tanzania, Mozambique and Zimbabwe (figure 8). Campbell et al. (1996) has estimated that in 1990, 40 million people inhabited Miombo areas with an additional 15 million urban dwellers relying on Miombo wood or charcoal as an energy source. Today, expanding urbanization, agriculture and forestry practices have heavily decreased Miombo cover. Misana et al. have stated that in Malawi 95 % of natural Miombo cover have been heavily modified and in Tanzania and Zimbabwe woodlands are mainly secondary Miombo forests (Campbell et al. 1996). Miombo woodland usually limits between latitude 10 and tropic of Cancer where long and heavy rainy season (4-5 months) alternates with long and rough dry season. The annual precipitation is around 650-1800 mm/year. However, Miombo is usually separated into wetter Miombo (precipitation >1000 mm/a) and drier Miombo (precipitation <1000 mm/a) according to the rainfall (Niemelä 2011). The mean temperatures are in coldest month 16.9 °C and in hottest month 23.3°C (Campbell et al. 1996).

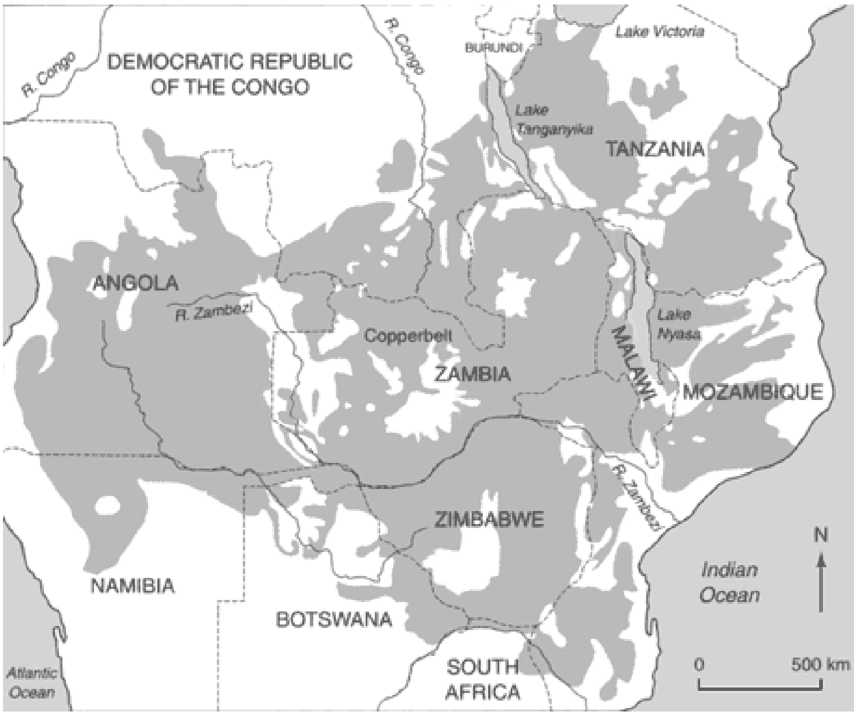

Figure 8. Miombo distribution (Mistry J. 2000 – Use of the picture is promised by Steve Ball, Chief Technical Adviser Mpingo Conservation & Development Initiative 05.03.2013)

Other general features are that the woodlands are usually located to geologically old, nutrient poor soils. Fire is a common feature in these areas (figure 9). The adaptation to fire can be seen from the Miombo species as the branches and foliage are usually a high level and tree trunks have protecting cork cover. Many times the fires are caused accidentally by humans who are preparing the land for cultivation or with purpose of control pests or clear the area alongside paths between settlements. Sometimes collection of honey, making charcoal or fire set by hunters or livestock owners are the causes of burning. Usually the fire occurs during the dry season from May to November (Frost 1996).

Figure 9. Fire in the study area (Picture: M. Suomela 2012)

Typical Miombo field layer plants are C4-grasses. Especially in wetter Miombo woodlands grasses grow high (1m-3 m) and in both variations (wet and dry Miombo) grasses are adapted to fire. Genera like *Brachiaria*, *Melinis* and *Hyparrhenia* are common. Fluctuation of grass species is usual between rainy and dry seasons (Frost 1996, Niemelä 2011).

The climatic conditions of Miombo areas have created highly weathered soils. Textures like loamy sand, sandy loam and sandy clay loam are likely to be found in both the top and subsoils (Campbell et al. 1996). Most of the soils have good permeability because of the microaggregation of clays. This means that the soil moisture is usually present at growing season but the land suffers from rough aridity at its driest time. The soils are typically acid and cation exchange capacity and nutrient levels are low. The same is with organic matter levels which are usually low as well, however those levels are highly related to the amount of wooded vegetation. Frost has presented in the book: The Miombo in Transition: Woodlands and Wellfare in Africa (Campell 1996) an overview of nutrient levels in different Miombo sites (Chapter 2, table 2.3).

Plant production studies in Miombo woodlands are limited. The general suggestion is that growth rates in Miombo are low. Most of the trees are deciduous and produce their new growth during or before the rainy season. Some of the data shows that the mean annual increments in biomass in regrowth woodlands in dry Miombo range from 1.2-2.0 mg ha $^{-1}$ and in wet Miombo 2.2-3.4 mg ha $^{-1}$ (Frost 1996).

5.2 Methods

The field work for the case study included interviews of farmers and the project farm characterization. The interviewees were randomly chosen local farmers and projects farm managers (farm lessees).

5.2.1. Interviews of local farmers

A total of 40 local farmers' interviews were carried out. Three of those were pilots, which make the total number of the analysed interviews 37. Interviews took place in all seven parts of Dzivaresekwa (figure 10). The first farmer interviewed was selected randomly from Dzivaresekwa I. A modified random sampling scheme was used, in which the selection of the houses is based on observation of cultivation in affiliation with the household. This meant that only houses with cultivations were chosen. The intention was to get the following interviews from every tenth house or more with the target of getting a general picture of each Dzivaresekwa area. In some cases the count was modified because of the house characteristics did not correspond to the objective of the study. The main focus was in the houses with growing trees. Some of the interviews were recorded with Digital voice recorder – Olympus WS-813 depending on the farmers' wishes. The house or field location was recorded with GPS devise - Magellan Navigation triton 400 (global position system).

A semi-structured questionnaire was used for the interviews. This kind of interview leaves space for new questions as the researcher is present for the whole interview and is asking the questions while making notes from the answers. This method is usual for studies where the interviewee might be illiterate (Aaltola 2007). The advantage of an interviewed questionnaire is the possibility for interviewer to underline some words for more attention or itemize some of the questions. The problems may arise if the researcher does not notice him/her emphasizing the words or steering the discussion for desired answers in another way. In a case like that there is a risk for unreliable results. A semi-structured questionnaire makes the analyzing of the results easier because the questions are simple and the basic data is already on paper.

There were two different parts in the questionnaire as it was proposed in Nair's book (1989): questions according to the agroecosystem and another part for socio-economic characteristics of the farm. The aim was to get a general picture about the farming environment and farmers' possibilities of making some reliable conclusions. Both quantitative and qualitative data was collected.

From Dzivaresekwa I, eight farmers were interviewed. This district can be characterized with high building density. Big families, small gardens and lots of household dump can be found as well. As this section was built first, it is still one the busiest areas of Dzivaresekwa. Local hospital (Rujeko-clinic) and Dzikwa Trust - Aids orphans education centre can be found from this section. Dzivaresekwa II differs from the Dzivaresekwa I as it is bigger area and consist a larger houses and bigger gardens. Locally Dzivaresekwa II is found wealthier and calmer from other Dzivaresekwa sections. From Dzivaresekwa II four farmers were interviewed. The northern end of the project farm is in Dzivaresekwa II.

The major part of the project farm is in Dzivaresekwa III. Dzivarekekwa III was covered by eight interviews, which included one school garden as well. The area is Dzivarekwa's biggest and it includes lots of schools and gardening plots. Dzivaresekwa IV is the smallest part in Dzivaresekwa. The southern end of the project farm is in Dzivaresekwa IV. There were only three interviews completed in this section because of its small size (as well as two of the pilots). Dzivaresekwa extension is located in north-west of the Dzivaresekwa. It can be found more separated part from other Dzivareskewa areas as it is built later and is still expanding. Four interviews were carried out from the Dzivaresekwa extension. Tynwald is separated to different parts from which Tynwald south belongs to Dzivaresekwa. This area is relatively big so five interviews were collected from Tynwald south. Kuwadzana phase 3 is the seventh part of Dzivaresekwa. This part is also relatively new in Dzivaresekwa (built in the beginning of 1990). The houses were a bit bigger like in Dzivaresekwa II as were the gardening plots. Kuwandazana phase 3 area is quite big therefore five interviews were collected in this site.

Data collected was run through PAWS Statistics 18 computer programme to recognizing the connection between different variables. Spearsman’s and Pearson’s correlation analysis were used. Mapping was carried out with the use of ArcGis-ArcMap version 10.

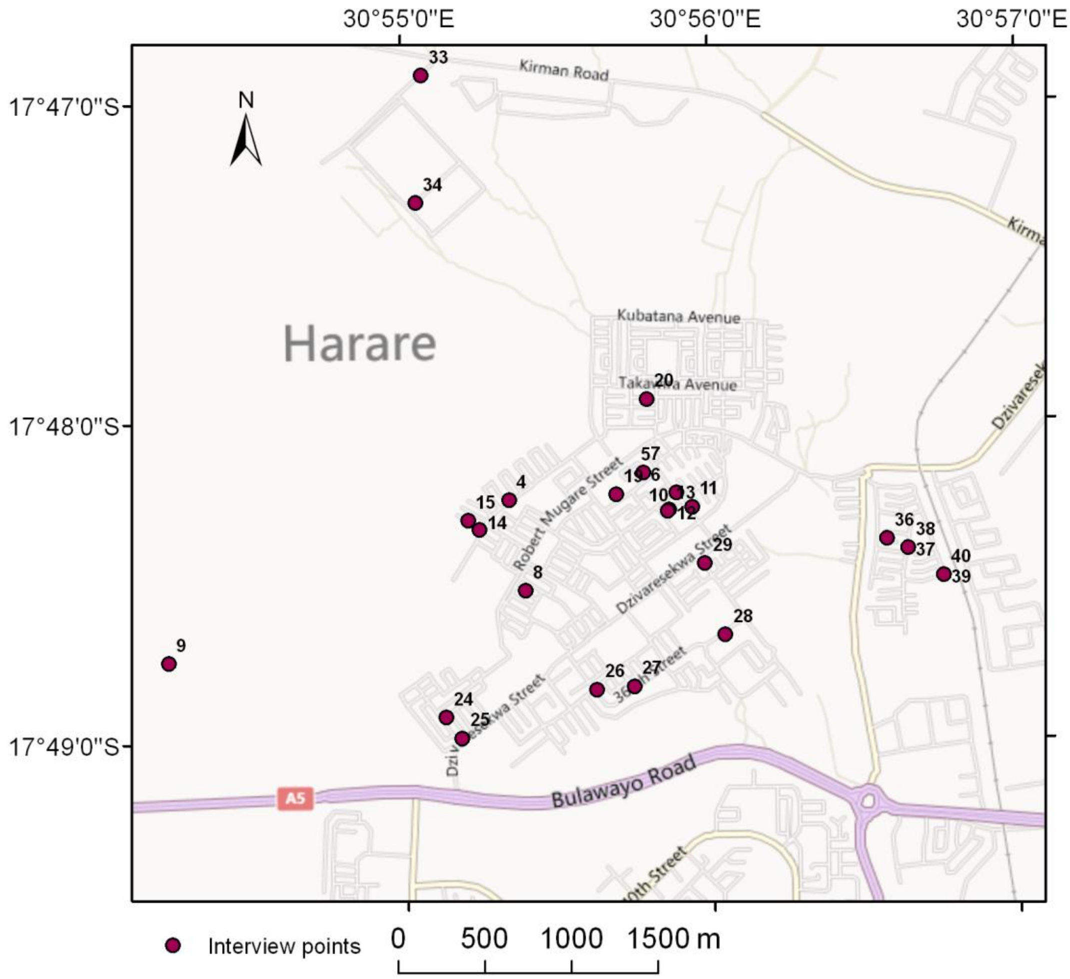

Figure 10. Locations of interviews of local farmers
(basemap from ArcGis - ArcMAp version 10)

Table 1. Notable variables and definitions in the questionnaire

Variable	Definition	Description
Aroecosystem		
Field cropping	Only crops are growth in the farm	Monoculture: only one herbatious specie is grown
		Mixed: 1-2 herbatious species are grown in the same plot (no woody plants)
Agroforestry	Crops and woody plants are grown in the same system	Homegarden: herbaceous and woody species growing in a same system and next to the house
		Other: woody and herbaceous species growing in mixture and in many layers (no clear connection to the location in relation to house)
Pasture/grazing system	Cultivation for animals	
Orchard	Cultivation mainly for decoration	
Size		
Garden/field	Cultivation area < 0.5 hectare or 1 to 2 small plots/farm	
Small holding	Cultivation area 0.5-1.0 hectare or >2 small plots	
Small farm	Cultivation area >1 hectare	
Large farm	Many >1 hectare cultivation areas	

5.2.2 Agroecological characteristics of the project farm

The project farm characterization included data collection by soil sampling and observation. The total area of leased land was 90 hectares, but the soil analyses were carried out only from the potential sites for agroforestry system, covering about 85 hectares. Soil sample plots are presented in figure 11.

Sample plots were selected randomly by regular transect sampling protocol. The first plot was chosen with lottery by standing in the southern end and eastern corner of the project farm and picking up a number from 1-10 out of the hat which gave the first meters to walk left. The second lottery number directed the turn to right in meters. From the first point 10 m X 10 m sample plot was measured using forest inventory margin ribbon (Fxa 50m). The sampling points were chosen by using the same method, starting from the right corner of the plot (the

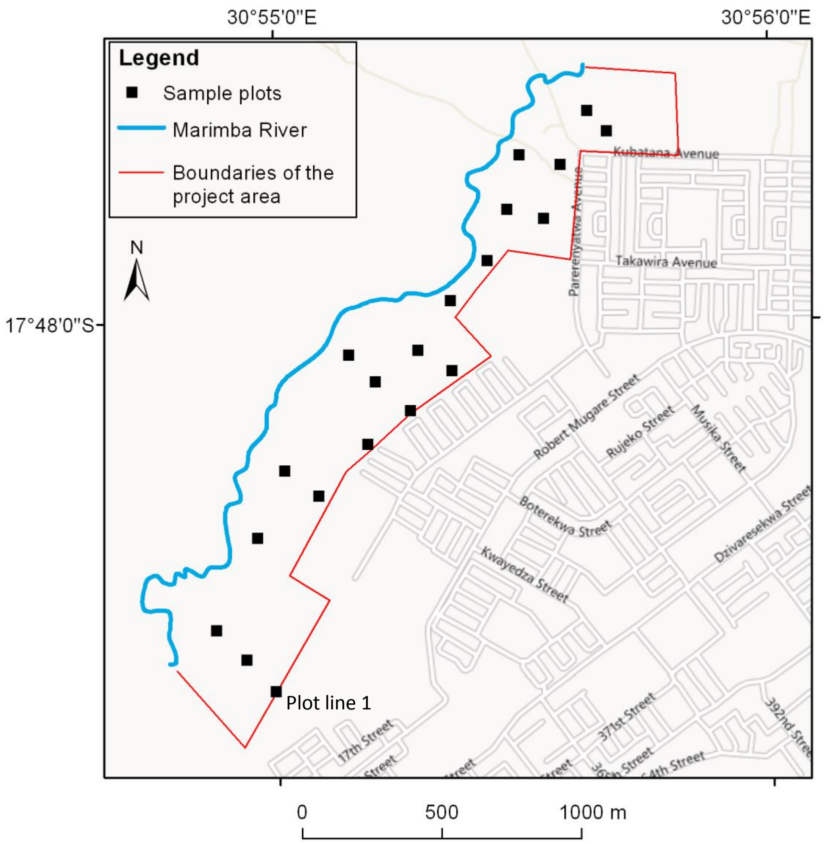

Figure11. Sample plot placement in the project farm
(basemap from ArcGis - ArcMAp version 10)

point that was the end up point from the first lottery). From the first plot, the whole area of 85 hectares was dealt for 20 plots transect measuring about 150 meter horizontal (east-west) interval[1]. The spacing in vertical (south-north) plot lines was around 200 meter. Four soil samples were taken from each plot by using a soil auger (diameter 3cm, length 50cm). The samples were taken from the uppermost layer (0-20 cm depth). Each of the sample plots was recorded with GPS devise-Magellan Navigation triton 400, for later analyses. Overall 4 x 20 = 80 samples were collected. The samples were stored in 0.5 litre volume freezer bags (Minigrip). About 5dl of soil per sample was needed for the analysis. After sampling, the samples were left for air-drying before the laboratory analysis.

The parameters analyzed from the samples were basic nutrients: initial and after incubation nitrogen (N), available phosphorus (P), exchangeable cations: potassium (K), calcium (Ca), magnesium (Mg), soil organic matter content, texture and pH. All the laboratory analyses were done in local laboratory by expert (Tauro T.P. 2012; Principal Research Officer at DR & SS); Research Services Division, Chemistry and soil research institute). The final analyses were decided in co-operation with the laboratory expert. All the samples were air-dried, pulverized and filtered through 2 mm sieve. Table 2 presents the methods used for the analysis.

[1] The spacing varied between 100-150 m in horizontal and 200-300 m in vertical plot lines because of the outstand circumstances.

Table 2. Methods for the analysis (Tauro 2012, Manzungu & Mtali 2012)

Parameter	Analyse method
Initial and after incubation nitrogen (N)	Mineral nitrogen was extracted using KCl solution and determined spectroscopically
Available phosphorus (P)	Phosphorus was extracted by resin method (Anderson & Ingrams 1993) and determined spectroscopically
Exchangeable cations: potassium (K), calcium (Ca), magnesium (Mg)	Exchangeable bases were determined after ammonium acetate extraction. Determination for exchangeable K concentration was made by flame emission photometry and for Ca and Mg it was made by atomic absorption spectrophotometer
Texture	Bouyoucos hydrometer method (Gee & Bauder 1986) was used for measuring the relative proportion of sand, silt and clay in the each soil sample. The soil texture category was determined by using a soil triangle by FAO (1990).
Soil organic carbon (C) content	Analyzed by accredited laboratory methods (DR & SS)[2]
pH	pH was measured with a pH meter in a 1:5 soil: $CaCl_2$ suspension

5.2.3 Interview of the project farm managers

The project farm managers' interview was based mostly on Jaenicke et al.'s proposal for farmer's interview. The questions were targeting to finding out the exact needs and desires as well as possibilities for the farm. There are two lessees for the projects farm, so they were interviewed at the same time. A semi-structure questionnaire was used as in interviews of local farmers.

[2] Despite the data for analyse methods used by the research laboratory (DR & SS) was asked several times, the data was not available at the moment.

5.3 Results

5.3.1. The interviews of local farmers

Figure 12 presents size of the farms. Most of the farms in all regions were in size of a garden (86 %). Only 3 % (1 farm) was in size of small farm, the farm was found from Snakepark, surrounding area of Dzivaresekwa. This area does not have much population; nevertheless the area is under a construction. From all of the visited farms, 11 % (4 farms) were in size of small holding, three of them located in Dzivaresekwa III. The questionnaire included four different sized characters from which large farms were not found. The exact size of the farms was usually not known but in general the farm area was <1 ha. In Snakepark the total cultivation area for the interviewee was 30 ha, but this was not all in the same place.

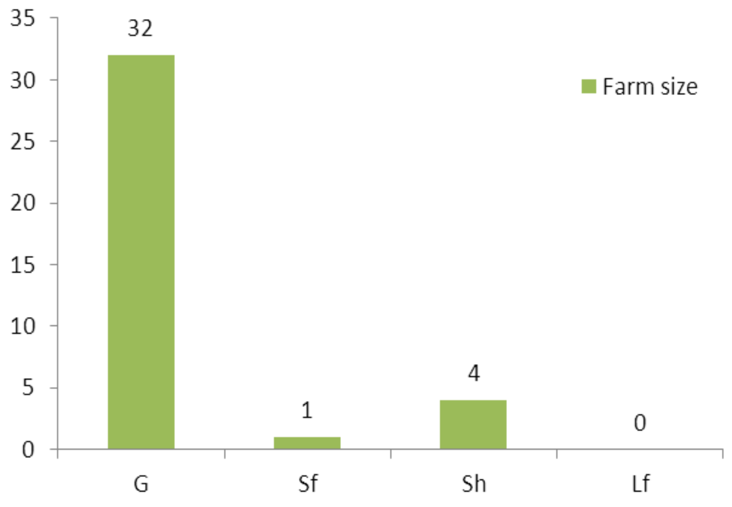

Figure 12. The size of the farm in all the Dzivaresekwa areas (G=garden/field, Sh=Small holding, Sf=small farm, Lf=large farm)

Figure 13. Plots outside the house in Dzivaresekwa 3 (houses located another side of the road) (Picture: M. Suomela 2012).

Figure 14. Covo (*Tronchuda portuguesa) (*Picture: M. Suomela 2012)

The major parts (87 %) of the farms were a type of an agroforestry systems; 24 % other than homegarden and 63 % homegarden (figure 15). Dzivaresekwa II and Tynwald south had only homegardens, but most of the gardens in Dzivaresekwa III presented other agroforestry systems. Most of the agroforestry systems were plots outside the house. The major difference between homegarden and other agroforestry systems was the location of the trees. In homegardens trees were not growing in mixture with plants as they were in agroforestry systems. Many times the trees were in other side of the garden or next to the vegetable plots. In agroforestry system the plants and trees were both growing inside the plot. Only two monoculture cultivations were recorded (5 %) from which one was both monoculture and agroforestry system. This household had two cultivation places: one in within the property and other, monoculture for maize, outside the fence. Mixtures in different parts of Dzivaresekwa were recorded 8 % in total (3 farms). In these farms trees were not included or were clearly separated from other cultivations.

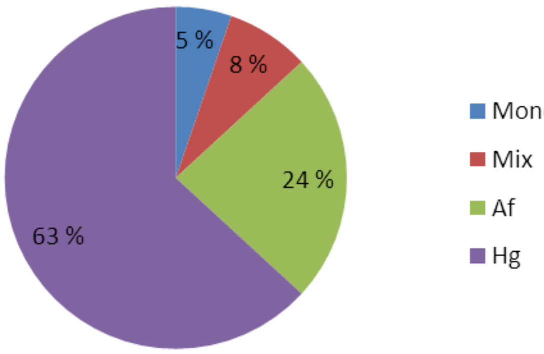

Figure 15. Farming type (Mono= monoculture of herbaceous) Hg= Home garden, Af= Agroforestry (other), Mix= Mixture of herbaceous)

Covo (*Tronchuda portuguesa*) was clearly the most common plant cultivated (52 %, Figure 16). If covo was not mentioned as the main plant it was still found from almost every farm. This made it different from maize which was told to be the main cultivation plant in 24 % (13 farms) of the farms. In most of the cases maize was either the main plant or not grown at all. The third main cultivation group was other vegetables which included mostly onions, tsunga (*Brassica juncea*), beans and tomatoes. In these results it must be noticed that one farm could have many main plants.

Trees were not found as the main species in any garden. When asking about the tree species, two of them, mango (*Mangifera indica*) and avocado (*Persea americana*), were clearly the most common ones (figure 17). A quarter (27 %) of the farms had mango tree growing in the garden and 21 % had avocado. There were only three farms which did not have either mango or avocado trees. However, some woody plants were growing in all places. The category “other” included species like muzhanzge (*Casimiroa edulis*), mulberry (*Morus alba*) and musau (*Ziziphus mauritiana*) and this part covered 12 % of tree species recorded. Rest of the tree species (peach, lemon, banana etc.), were found almost the same amount (≤ 10%).

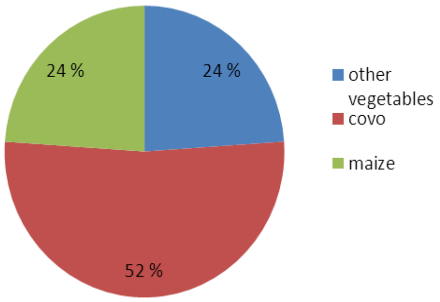

Figure 16. Main cultivation plants (covo=*Tronchuda portuguesa*, maize= zea mays)

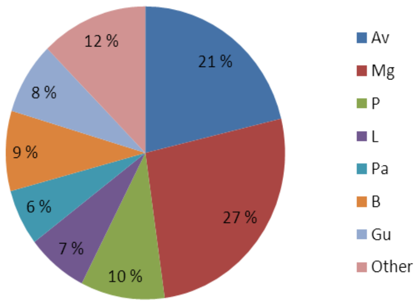

Figure 17. Tree species in the farms (Av= Avocado (*Persea americana*), Mg= Mango (*Mangiferaindica*), P= Peach (*Amygdalus persicae*), L= Lemon (*Cirtus lemon*), Pa= Paw Paw (*Crica papaya*), B= Banana (*Musa sp.*), Gu= Guava (*Psidium guavaja*)

The purpose of the trees was biased (Figure 18). Only two farmers did not grow trees for fruits, because these trees species were not fruits trees (Eucalyptus and sickle bush). Firewood was generally needed but the trees growing in the gardens were not much used for this purpose. Only five farms told that they use the trees for firewood. Manure, shadow and medical purposes were mentioned as well, but the proportion was fairly small (3-5 farms).

Irrigation was common in all Dzivaresekwa areas, as 30 of the 37 farms told to irrigate. Seeds were the most common input, but fertilizers and pesticides were also used more than a half of the farms. Seasonal rotation was usually implemented; 12 farms did not use any rotation plan. Plots outside the homestead were not very common; less than half of the farms told to have another cultivation plot than the one near to the house. Almost all farms (two exceptions) used only family as labor and the cultivation target was mainly home use. Only ten farms were also selling some products.

Connection between different variables in interviews of local farmers, were usually not significant (p-value > 0.01 at the level of 0.01 significance). Some correlation was recorded between farm type and farm size as the level of significance was < 0.01 (p-value 0,000). It was noted that, homegardens were most commonly the size of a garden. Correlation between Dzivaresekwa areas and farm size or farm type was not significant (p-value >0.05).

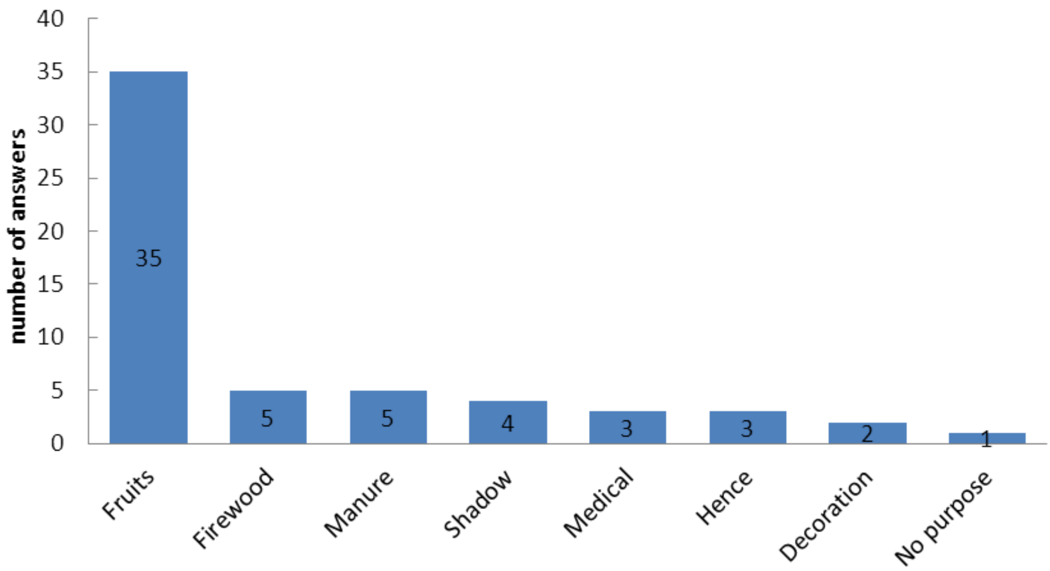

Figure 18. The purpose of trees

5.3.2. Agroecological characteristics of the project farm

Slope:

The project farm was generally flat. Differences in altitude can be found in detailed measurements; highest altitudes to be situated in the northern part of the project farm and getting lower in the direction to south-west. In the eye level, big slopes cannot be noticed. The farm contains small ditches, which are dug for agricultural use. These ditches are not deeper than 1 m and with the wideness of 0.2-1 m. In the northern part of the farm, where agriculture is more common, bucket systems of ground water can be found in deepness of 2m. Some leftovers from the project farm's use as city's rubbish dumping place can be seen as pile ups of trash in the highness up to 2.8 meters. These pile ups were mostly located in the southern part of the farm, between plot lines two and three (figure 11).

Physical soil characteristics:

Based on the soil sample analyses the main soil class was identified as fine sandy clay loam (fSaCL). This was recorded from 16 samples of all (total number of samples was 80) (Figure 19). The second common soil type was medium coarse sandy clay loam (mSaCL) which was

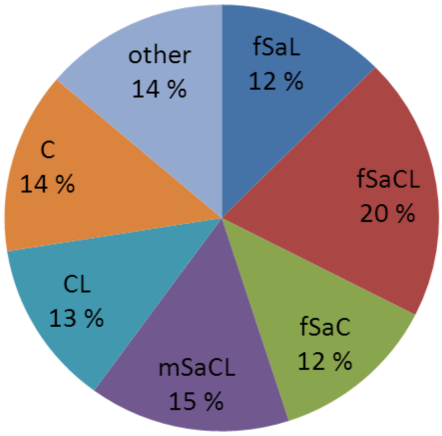

Figure 19. Percentage of different soil types. S=Sand; C=Clay; SaL=Sandy loam; SaCl=Sandy Clay Loam; f=fine; m=medium; c=coarse

identified from 12 samples of all. And the third, covering 11 samples, was clay (C) (Figure 19). In total 12 different soil types were recorded.

Organic carbon content averages varied from the 1.3 % to 4.26 % (Figure 20). The highest percentages were found from the plots textured as clay loam or clay. Respectively, most of the fine sandy clay soils had low organic matter content. The total mean was 2.47 % of organic matter in one plot, but as it can be noticed from the figure 20, the organic matter content varied a lot even the texture remained the same. For example, when looking at the most common soil type fSaCL (figure 19) the organic matter content changes in a plot means between 1.49 % and 2.74 % (figure 20). The variation between fSaCL samples in relationship with organic carbon content was 1.13 %-3.92 %. From figure 21 can be noticed that most of the texture types are richer in sand than clay. Only couple plots had higher clay than sand percent. The project farm showed a high fluctuation in texture, but in general it can be characterized as fine sandy loam soils.

The results from the soil analyses showed a high variation. In general most of the plot means are above the medium levels or even higher than the announced high level. However, the connection between the location in the farm and the level of values is not distinct. For example plot 4 showed great differences in almost all parameter levels (except organic carbon %) compared to plots before (plots 1-3) and after (plots 5-6). The variation even inside the plots could be clearly noticed. When looking at the pH levels recorded from the plot 11 and 7 the lowest level is 4.3 and 4.8 and highest 6.3 and 6.3. In plot 7 the variation is also high in values of available phosphorous as the lowest level is 62 ppm and highest 236 ppm, which is extremely high. Similar kind of extremes inside the plots could be found from all of the other parameters analyzed, except from magnesium levels.

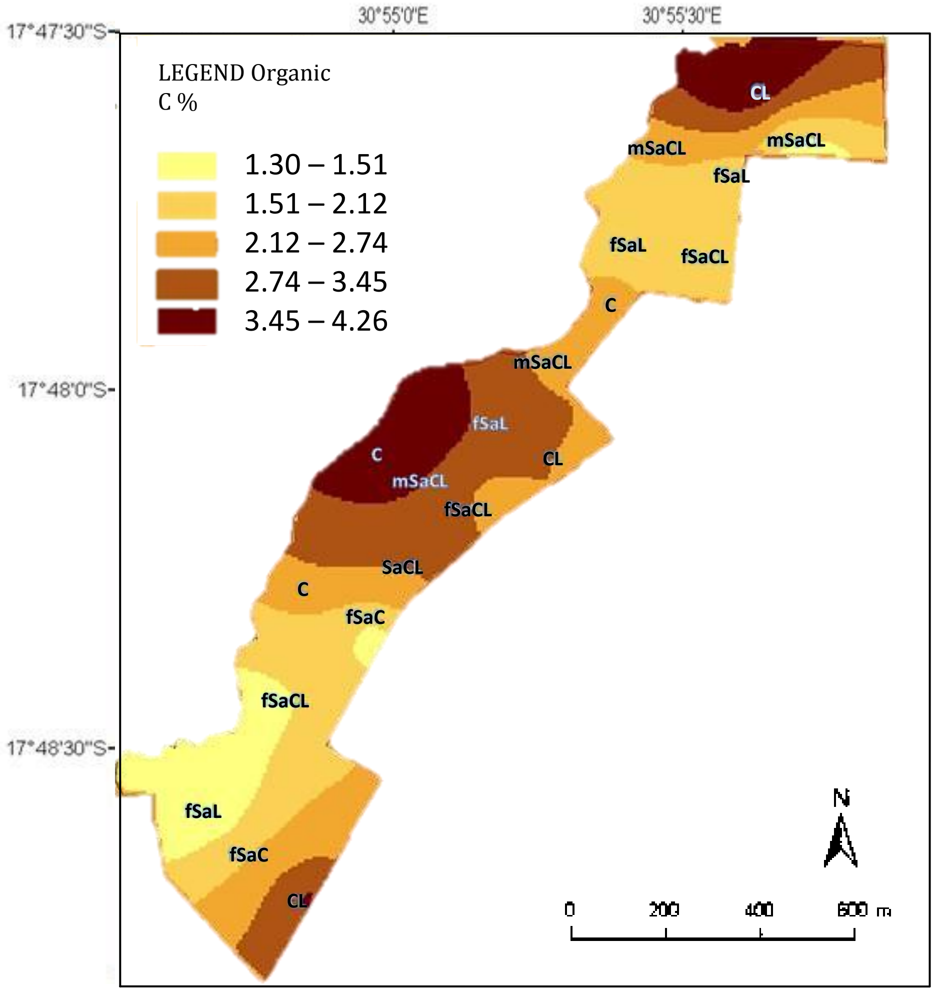

Figure 20. Organic carbon percentage stacked up with plots' main soil texture located in the project farm. S=Sand; C=Clay; SaL=Sandy loam; SaCl=Sandy Clay Loam; f=fine; m=medium; c=coarse

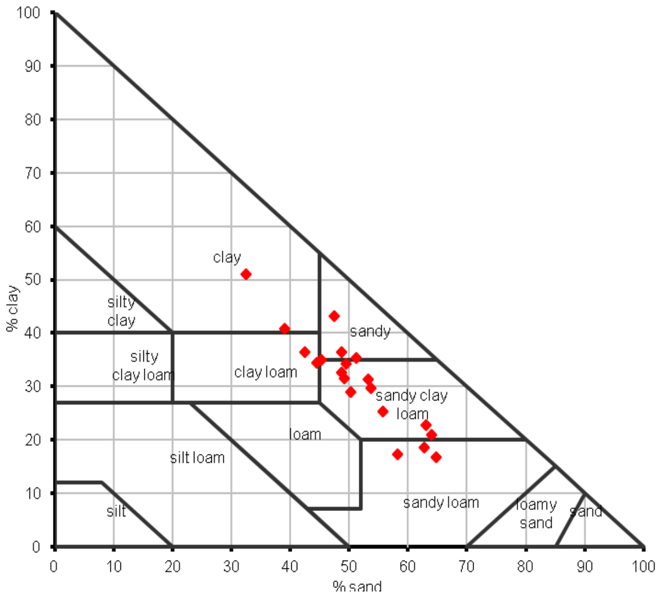

Figure 21. Soil particle size analyze. Accumulation of clay and sand persent in the soil samples.

When looking at the soil analysis results in more detail, the pH levels have clearly low levels in the plots 4, 12-13 and again in plot 17 (pH <5) (figure 22). The high levels were recorded from plots 1-2, 5, 16 and 20 (pH >7). In this sense, the alliance between the location at the project farm and the pH levels cannot be noticed.

The same can be noticed from the exchangeable cation levels (figure 23). Especially calcium rates showed two peaks in plots 5 and 16, reaching the level of 81.55 mg equivalents/100g and 80.30 mg equivalents/100g. According to DR & SS these levels are extremely high as >10 mg equivalents/100g is classified as a high level. The total minimum for calcium (including all samples) was 1.48 mg equivalents/100g and total maximum 86.72 mg equivalents/100g.

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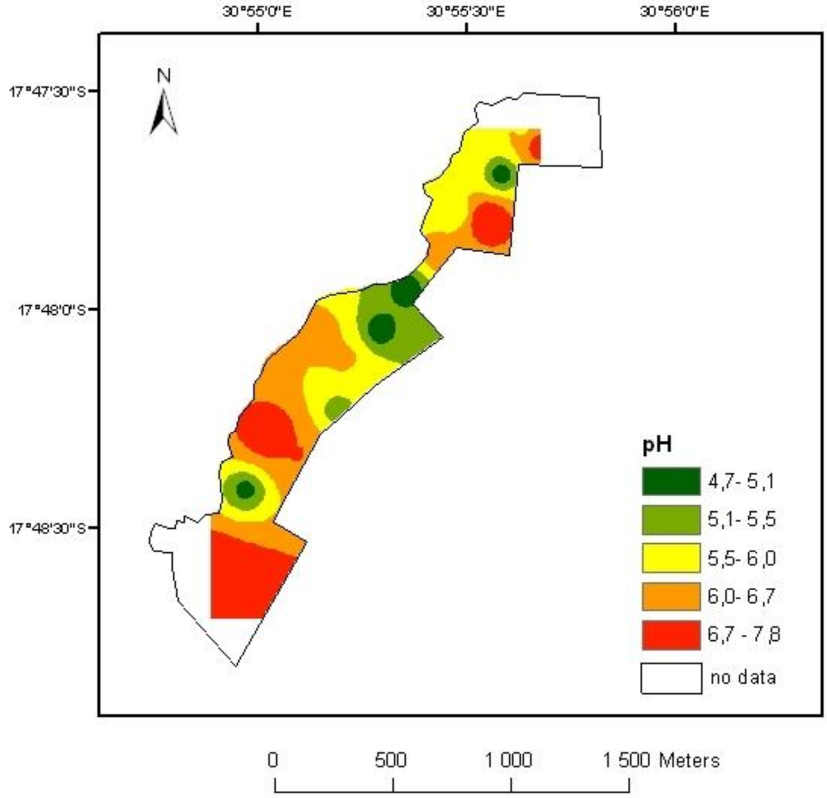

Figure 22. The average pH levels in the project farm

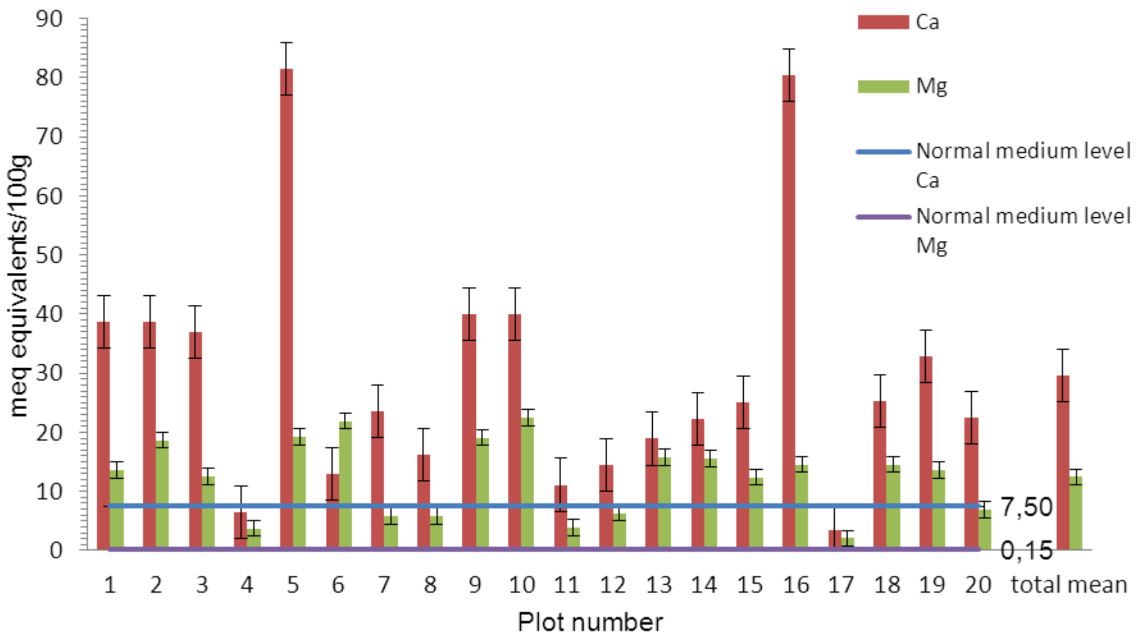

Figure 23. The avarage calsium (Ca) and magnesium (Mg) levels (meq equivalents/100g) by plot with total mean and normal medium levels (given by the DR & SS).

Magnesium levels were the most stable variables measured in the whole project farm area (figure 23). The variation was between 1.78 mg equivalents/100g to 26.88 mg equivalents/100g. However, the rates were exceptional high. Even the lowest level (1.78 mg equivalents/100g) was higher than high level given from the research laboratory (>0.2 mg equivalents/100g).

Available phosphorus (P) showed very high variation between plots (figure 24). There were three extremely high peaks; 158 ppm, 266 ppm and 152 ppm, and two very low levels; 4 ppm and 7 ppm. The total plot mean was 62.65 ppm which was interpreted as high (Appendix , annex 3. Table 1). However, when looking at the impact of soil pH to P levels, it can be noticed that almost all sample averages are under the neutral pH level (pH < 7), in which phosphorus is the most available (figure 25).

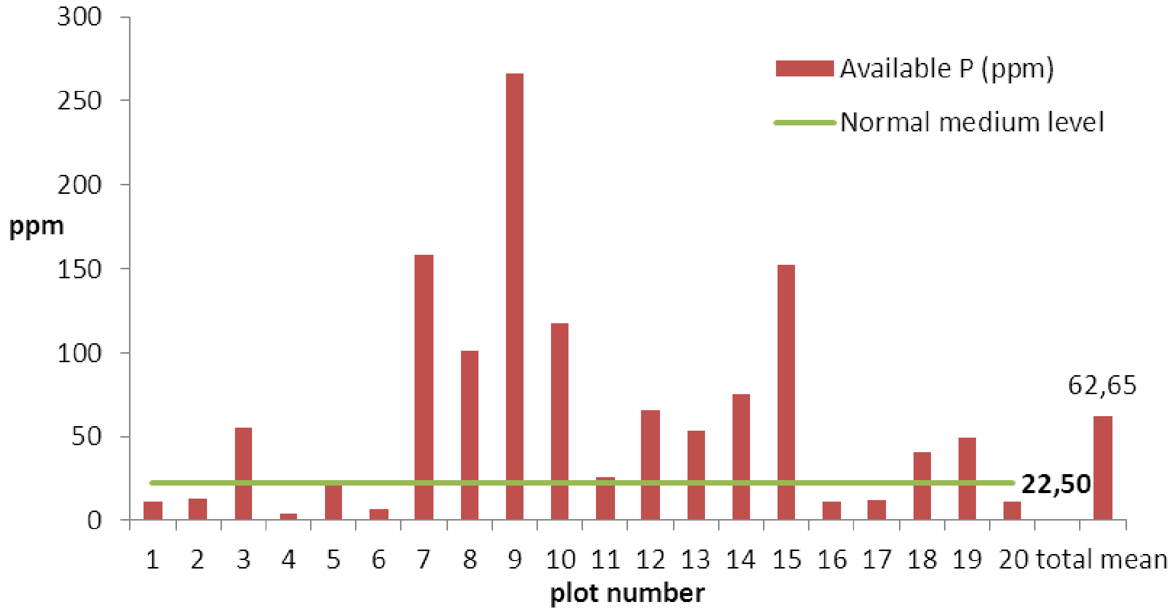

Figure 24. Available phosphorus levels with normal medium (DR & SS)

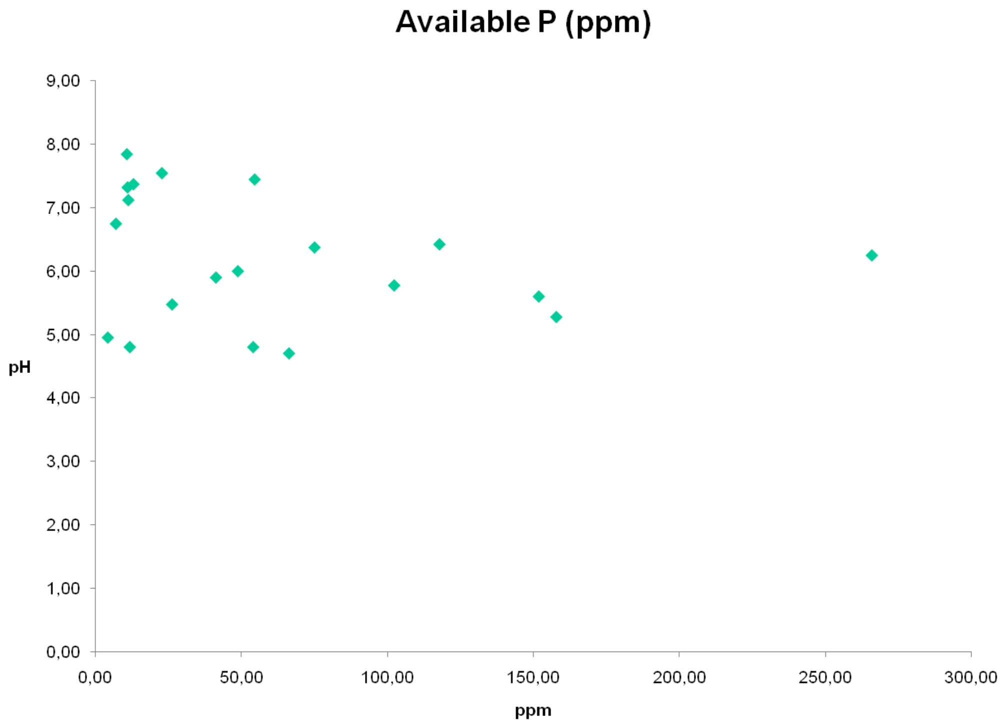

Figure 25. Impact of soil pH to available phosphorus (P) levels

Potassium levels, in general, were very high and variation between and inside the plot could be noticed (Figure 26). From the plot average levels three peaks were recognized: 2.03 mg equivalents/100g, 2.02 mg equivalents/100g and 1.24 mg equivalents/100g. However, the levels stayed over 1.20 mg equivalents/100g also in plots 8, 9 and 11. The maximum potassium level was recorded from the plot 10 (ref. numb. 10D). The minimum level was found from the plot 4. The total mean was 0.81 mg equivalents/100g which is characterized as high level (>0.5 mg equivalents/100g). Potassium levels varied quite a lot within the plots. For example in plot 3 the values were between 0.43-3.08 mg equivalents/100g and in plot 11 between 0.41-2.73 mg equivalents/100g.

In figure 27, the initial and after incubation levels for nitrogen (N), as well as N-mineralization levels after incubation are shown. In general, the levels are high. The total average after the incubation was 48.75 ppm, which is 8.75 ppm more than the limit of high in general fertility range. The net N-mineralization rate correlated mainly with the after incubation curve. The highest N level in after incubation curve was in plot 7 and the lowest in plot 14 and the similar flow is presenting the extreme levels in N-mineralization curve as well were the highest level is again at the plot 7 (60 ppm) and lowest at plot 18 (12.5 ppm), which is the second lowest level at after incubation levels. Relation between net N-mineralization and initial N was not as strong.

Correlation between organic carbons content and net N-mineralization was notable. With all the plot averages included, the correlation was R^2= 0.171, which not very significant. However, when excluding two of the extreme levels (plots 10 and 19) the correlation was R^2=0.306, which relatively strong correlation (figure 28).

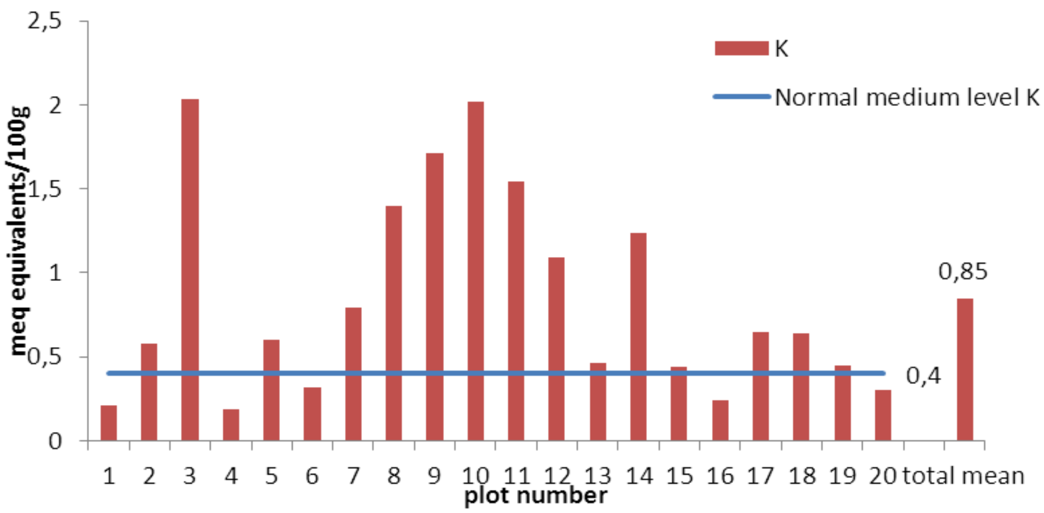

Figure 26. The average potassium (K) levels (mg/equivalents/100g) by plot.

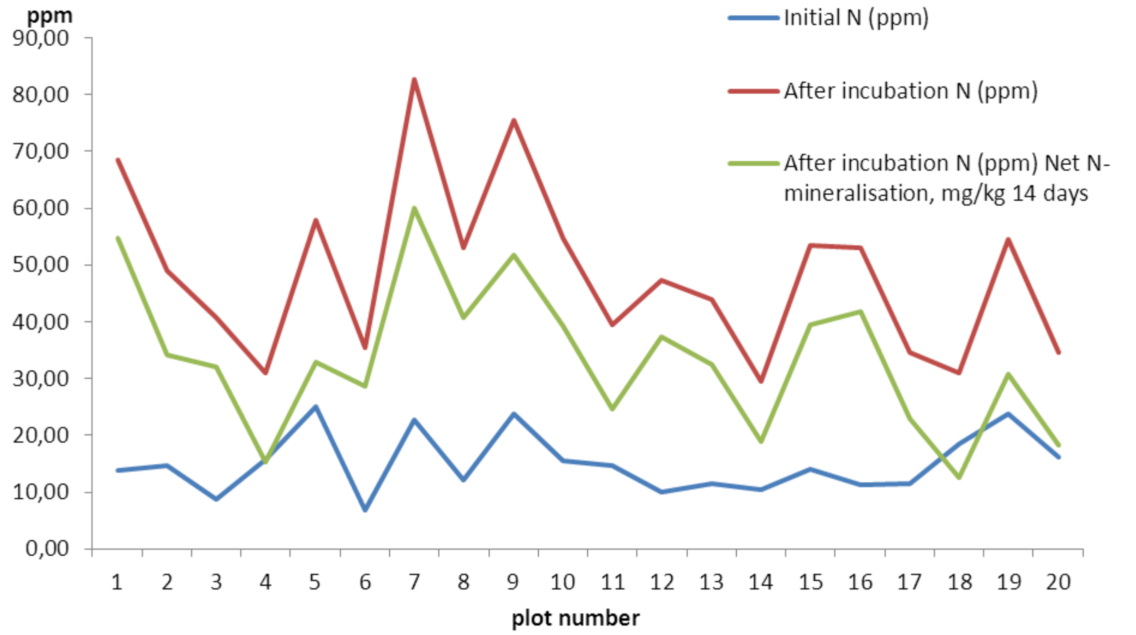

Figure 27. Initial and after incubation nitrogen (N) and net mineralization by plot average (ppm).

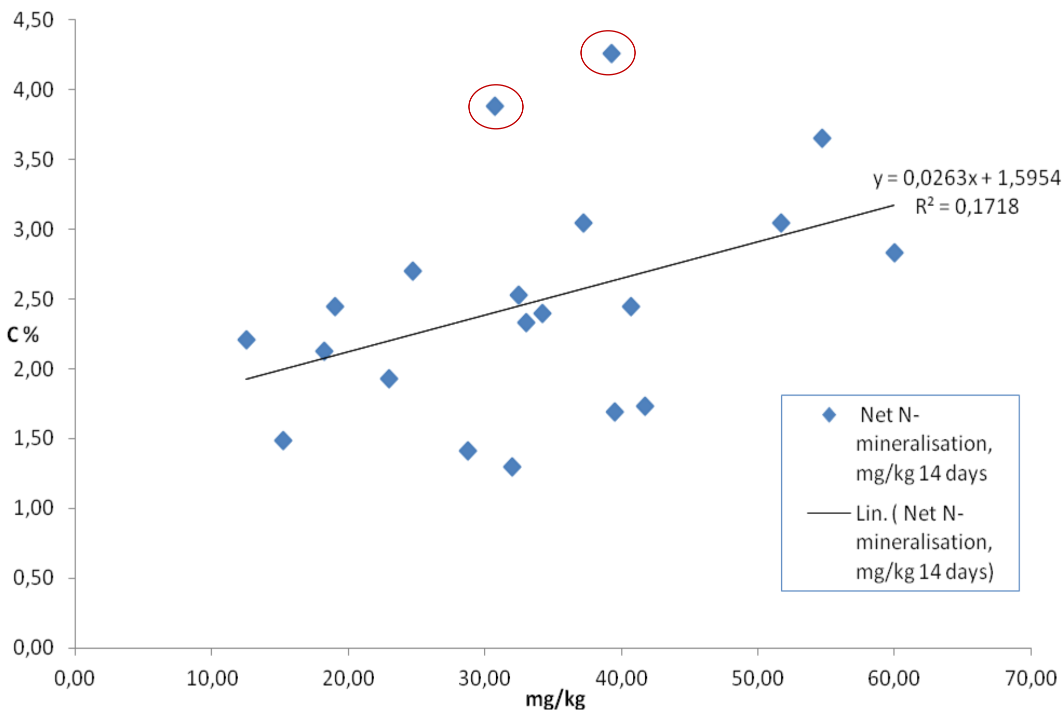

Figure 28. Correlation between organic carbon content (%) and Net N-mineralization (mg/kg). Extreme values from plot 10 and 19 are circled by red color.

Availability of water:

The eastern boundary of the project farm is Marimba River. The southern end of the stand is recorded as a wetland. Next to the south-eastern boundary, some digs have been done by the city council that has proved the access into high amounts of ground water. In the Graceland, the nursery, there is also functioning access to irrigation system by bore hole. According to these, water availability in the farm area is relatively good. However, there is no data available about the water purity.

Existing vegetation:

Weeds like black jack and robust star grass were the most usual recognized vegetation in the project farm. Close to the river the vegetation usually changed more into high river bank species like *Typha capensis*. Next and under Eucalyptuses the vegetation was poor. Natural vegetation was hard to describe because of the long lasted irregular land use. Natural tree species were not found but some of the existing acacias might remain from the original species composition.

List of most common weeds collected from the project farm is presented in table 3 (recognized in The Botanic garden-Harare herbarium).

Table 3. Common weeds in project farm

Common name	**Scientific name**	**Local name**
Black jack	*Bidens pilosa*	tsine
Robust star grass	*Cynodon nlemfuensis*	
Thunberg's amaranth	*Amaranthus thunbergii*	mohwa
Shoo fly plant	*Nicandra physalodes*	
Peruvian Black Mint/Southern Cone Marigold	*Tagetes minuta*	
Fine thatching grass	*Hyparrhenia filipendula*	Zhengezhu/dangaruswa
Rose natal grass	*Melinis repens*	
Bulrush/Love Reed	*Typha capensis*	
Goat weed	*Ageratum conyzoides*	
Whitewort	*Leucas martinicensis*	

Dump site description:

Most of the household dump sites were found along with the western boundary. There were also bigger and older dump spaces in the middle parts of the project farm. Apparently, the farm has been used as general dump site of the city of Harare. This could be seen as the higher parts of the project farm, which were piled up from trash. Dumping was still happening by local people. The waist consisted for example general from households' leftovers as well as parts of motor vehicles and clothes.

5.3.3. Interview of the project farm managers

The main production targets for the project farm was mentioned to be producing firewood, improving biodiversity conservation and rehabilitation as well as saw timber and fruit production. When asking about the by-products desired, maize, sorghum, vegetables (cabbage, spinach, rape, covo, tsunga etc.) were mentioned.

The farmers' point of view for irrigation was quite clear; they wished to locate plants in a need of irrigation, close to the nursery where the bore hole is located, otherwise irrigation was not desired. Some estimates for the possibility to invest for the project was given. During years 2012-2013, 80 000 euros are about to be invested in the project, but after that, investments are still an open question. The managers thought that the biggest expense will probably be the salaries for the project farm workers. The plan was to hire 3-5 workers for the project farm until 2015 and some occasional workers when needed. After 2015 the number of employees is hoped to be increased. The labor was thought to be mostly self-learned farmers or foresters. There was a wish to get some children from the Dzikwa Trust educational center to become interested about forestry and agriculture, in the way that they could be educated partly by taking a part in the project. Even a possibility for short courses about farming has been discussed inside Dzikwa Trust.

Seeds would be purchased from local Forestry Commission (tree seedlings), a local forest professional and other possible contacts. For the future, the idea was that most of the seeds would be produce in the own nursery. Some agricultural seeds are most probably bought from local markets or obtained as donations in the future as well.

5.4 Discussion of the case study results

The interviews of the local farmers showed pretty equal results. Notable variation between different Dzivaresekwa areas was not recorded. Agroforestry systems are common in Dzivaresekwa district, but the utilization of trees is poor. The main purpose mentioned for trees, was usually fruits, even the potential for firewood, shading and other is also present. Commonly, agroecosystems were in small size as the houses are built very dense. This makes the available space for trees limited.

The main cultivation species were clearly covo and maize. However, almost all farms cultivated also some other vegetables. Covo is easy to regenerate from its shoots, which makes it also cheap to grow. These might be some of the reasons for its popularity. Clearly it is also growing well in the area. Maize is the basic ingredient in Zimbabwean meal, so it was not surprising to find it so common. In Gumbo's (2000) research tsunga and rugare viscose were common in Harare. In Dzivaresekwa tsunga was also present, but rugare viscose not. The reason might be in confusion of species as rugare viscose is a subspecies for covo. In the other hand, in Zimbabwe tsunga is a traditional plant, which might be partly replaced by covo as it is used similarly.

A clear combination with trees and crops was difficult to notice, because the systems were built so differently. However, it seems that covo can be grown under trees like vegetables such as onions and spinach.

It was clear that fruits were wanted from the cultivations. Mango and avocado seems to be well adapted to Dzivaresekwa, as those were the main tree species found. The problem with avocado in agroforestry system can be its crown, as it grows easily dense and can disturb the growth of other species under the canopy because of the limited sunlight. Mango on the other hand, has thin leaves and has been successfully grown in some agroforestry systems (Musvoto & Campbell, 1995).

Ground water situation in Dzivaresekwa seemed to be good as many of the farms used irrigation by bugged systems. Some of the soil samples were also giving the picture of high existence of water. This is very important for the project farm because many of the plants cultivated need some irrigation.

From the socio-economic results, it was clear that the local farmers were cultivating with low investments. Employees were not used, inputs were mostly seeds, and water was taken usually from the rain or ground. Big farming areas were rare. This might be because of poverty or limited space, but most likely the reasons are multiple.

The timing for interviews was probably limiting the data collected, because the information about the plants cultivated during the rainy season was unclear. Interviews were done between May and July which are the months for maize harvesting (see the figure 1). It is hard to say if, for example, covo would have been the most common cultivation specie found during the rainy season. However, it can be said that the general overview of plants and trees grown was gathered.

The project farm characteristics showed high variation. When looking at the soil analysis it is hard to draw any clear conclusion. The nutrients levels did not show any constant frequency and there were no clear deposits of nutrient levels in any particular sites of the project farm. However, the results support the presumption that the project farm used to be a miombo forest. The wild grasses and the soil texture classification are similar to miombo characteristics. In this sense, it can be assumed that the trees and other vegetation adapted to miombo woodlands can be grown in the project farm.

Nutrient levels are important determinant to vegetation, so based on the project farm survey, only imprecise propose of appropriate species for the farm is possible to carry out. However, some conclusions can be presented. The levels of pH were usually between 5 and 8 which is suitable for many cultivation species. The high correlation between Net N-mineralization and organic carbon content tells about good nitrogen availability for plants to be used (Figure 28). This means that nitrogen should not be a limiting factor. Similar results could be concluded from the relationship of pH with available phosphorous levels. Phosphorous is in most available form ($H_2PO_4^-$) for plants in acid soils (pH <7), and the majority of the soil samples were recorded like this (Figure 25). Based on the soil analysis, it seems that there is no immediate need for nitrogen fixing trees (NFT's). However, use of NFT's should be considered because of their advantages for good soil maintenance.

Soil texture in the project farm was varying a lot, as it included both sandy and clayey areas. Most of the samples were characterized as fine sandy clay loams. Sandy soils are generally found as good in drainage and easy to cultivate, but water and nutrient loss can be difficult to control. Clay soils do not drain easily and are difficult to cultivate, but are good for binding nutrients and moisture. For tropical conditions clay loam (dry areas) and sandy loam (moist areas) are usually the best cultivation soils (Gliessman 2007). In this sense, the farm land should be fine for cultivation.

The reasons for variation and extreme values in soil analysis can be found from the farm's history and current use. Lots of small pathways can be found from the farm land, which are commonly used. The northern part is situated between Dzivaresekwa 2 and Dzivaresekwa Extension; so many people are walking daily through the farm land. In the southern end pathways to Dziverekwa 4, Bulawayo road and Snake Park can be found. These daily routes are stressing the soil and moving seeds and possibly pathogens around in and out the farm.

The shortage of firewood in Dzivarekwa is also threat for trees planted next to daily routes. An estimation of circa 500 farmers using the project farm area at the moment has been given by the locals. This is extremely high number for such a small area and includes cultivation techniques in high variation as well. This might explain some of the nutrient level variation as well. However, the main reason is probably in the history for the project farm used for a dumping ground. As mentioned, some parts are still under household dumping which probably impacts to the soil characteristics. A research by Rajbala and Bhaskar (2012) showed that levels of magnesium and calcium are common to increase in dump sites. This supports the results received from this study as well. In this sense, one of the recommendations for the farm would be a couple years long recovering period. This could be done by so called phytoremediation process where plants are used for cleaning up and recover the soil nutrient balance from soil pollution (Qixing et al. 2011, Wani et al. 2011). The recovery period would be important because of the high risk of water contamination through leaking nutrients and because of the possible risk of toxic nutrient levels for cultivation plants.

Some studies about the water purity next in Marimba River are undergoing but the results are not yet available. However, it could be assumed that the nutrient levels are relatively high in the water as well. For water protection, it is important to pay attention to the buffering zones between water system (Marimba River) and cultivations. The risk of nutrients leaking is high.

From the projects farm managers’ interview, the obvious objective for the farm was firewood production. However, the production of firewood was wished to be supported by other benefits as well. The inputs were wished to be low and the aim was to manage the system mostly by self-sufficient ways. This was restraining choose of species proposed. Irrigation was mentioned to be used only near to the nursery, so water consumption was also limiting the species selection. Educational desires and land rehabilitation objectives were supporting the selection of natural miombo species.

5.5 Agroforestry system design

The proposal for suitable agroforestry system is based on the results presented above, advises from the local expertise, agroforestry species database by ICRAF (online) and other literature.

The results obtained from the interviews of the local farmers and project farm characteristics are used as preconditions for the limitations and possibilities for the farm. Community, farmers' expectations and project farms ecological features (native species, climatic conditions etc.) has been taken into account when thinking about the suitable plant species. The further elimination has been done based on the soil analysis, suitability for agroforestry and management and growing characteristics of the species. The main drivers for the final design were the projects farm manager's needs in respects of the biophysical and ecological possibilities of the project farm.

Recommendations for species arrangement have been done based on the species growing characteristics and interaction with other species. Some trees might be found as allopathic or water/nutrient profligate which can be harmful for other species. These species cannot be grown in interaction with others.

Species presented in figure 29 are examples of suitable species for the farm sections. Some species proposed can be left out or changed to other similar species if wanted.

The list of species considered is presented in the Appendix, anex 2.

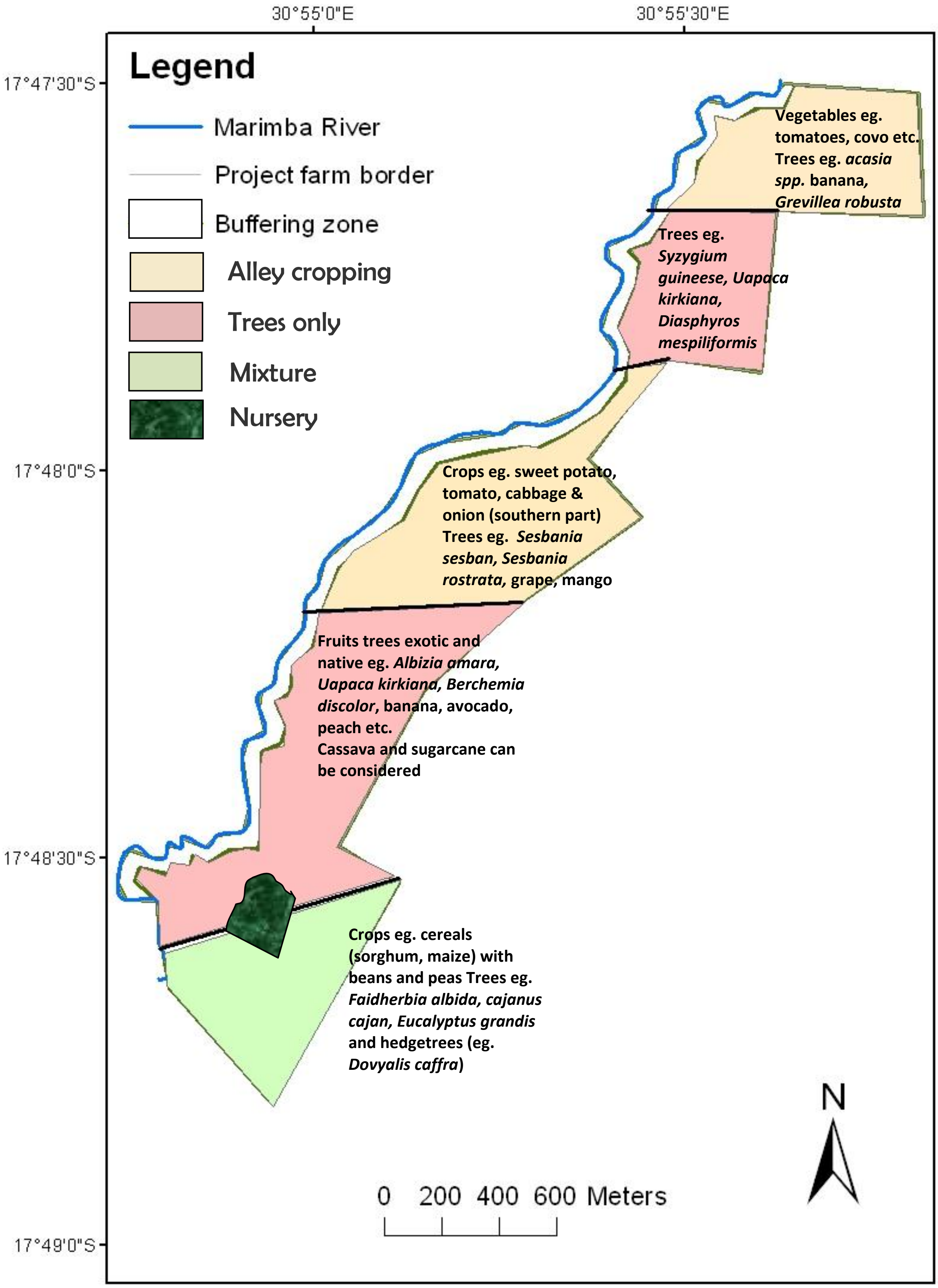

Figure 29. Proposed agroforestry design for the project farm

6 DISCUSSION

Designing an agroecosystem recommended, starts from discovering the very basics of the local ecological conditions and ends up with the analysis of detailed characteristics of the target farm. This kind of a process can be very time and finance consuming and that is why it is not possible to carry out in many cases. However, research has proved that well designed agroecosystem is more beneficial for both the farmer and the environment than one designed without background studies.

Peri-urban areas have a high potential to improve food and firewood shortages in cities through sustainable and efficient agriculture. It can also be a way to ensure self-sufficiency in food and firewood supply for farmers own household, by applying agroforestry system as a kind of agroecosystem for the farm. However, people living in peri-urban areas usually belong to low income groups who do not have much money to invest in any other than costs of living. This is one reason why it is important to know which crops are suitable for the local conditions for avoiding the loss of investments and income. Nevertheless, the process for establish a well designed agroecosystem has to be simple for most of the farmers.

One of the aims of this study was to gain more knowledge of designing a simple agroforestry system for peri-urban environment in a way that it could be easy to apply for various systems. The agroforestry design model proposed, included parts for biophysical and socio-economic evaluations as recommended in the theory used. The base for this model is scientific as in the three guidelines. It includes scientific analysis and evaluations as a part of the design process. These sections can be difficult to apply by local farmers. For ease application of the model, these parts should be modified into simpler form.

The case study for testing the design model was good way to become aware of the obstacles and points of the process that stick out. The farm had many challenges because of its history and previous utilization habits. The nutrient balance was very extreme most probably because of the history of dumping of trash. The daily pathways located in the farm are disturbing the cultivation and threating the survival of plants grown. The background information was difficult to find because of the instability of the country during the last decades. However, this kind of a case study gave realistic results for the design process. It was easy to notice that the process was still very time consuming and not very simple, even for a researcher. In this sense, it can be concluded that more work is needed to achieve an easy way to design a sustainable agroforestry system.

However, the design model gives a good frame for further development. It could be said that in a case of development of already existing agroecosystem the design process could be limited to project farm survey and farm manger’s interview. An interview of local farmers is useful in a case of designing a totally new system. The project farm survey could also be limited only to an observation, even though this kind of method does not give reliable results for suitable species composition. The problem in soil analysis, from the view of a farmer, is the high costs and need for understanding the results. This might be found too complicated and can be considered to be left out because of that. However, it would be important to collect some information about the soil conditions for successful farming system design. Soil analysis could be replaced by collecting data based on local understanding of species cultivation. In that case, it would be essential to knowledge the uncertainty of the results.

The biggest challenge for the study was the species selection part. The results from the project farm land analysis had such high variation that it was difficult to come up with any clear conclusions of the cultivation conditions of the farm. Information about the growth of agricultural species in high nutrient levels was limited, which made the species selection even more challenging.

Total time for the design process was around four months. This might be too long time for farmers already depending on agriculture as their income. However, when designing totally new agroecosystem the time consumed can be found reasonable.

Dzivaresekwa can be seen as a borderline case in a concept of peri-urban areas. Some might say that it is not full filling the definition of peri-urban area because of its high population density and too close location of Harare center. Nevertheless, even as borderline case, it acts as a good example of urban production possibilities. Because of the limited space, the farming system’s advantage can be seen in its diversity of products.

Urban context itself might set some expectations for the results of farming conditions (Craul 1999). In this case study, it was expected that soil fertility would be poor and the variability in the species composition would be small. In addition, the utilization of the species would have expected to be greater. In urban areas soil is usually overused and stressed which have caused some soil erosion and poor fertility. In this case the results showed the opposite.

Figure 30 presents a proposal for simplified version of the design formation process. The main changes have been done by excluding the theory part, as it could be assumed that some

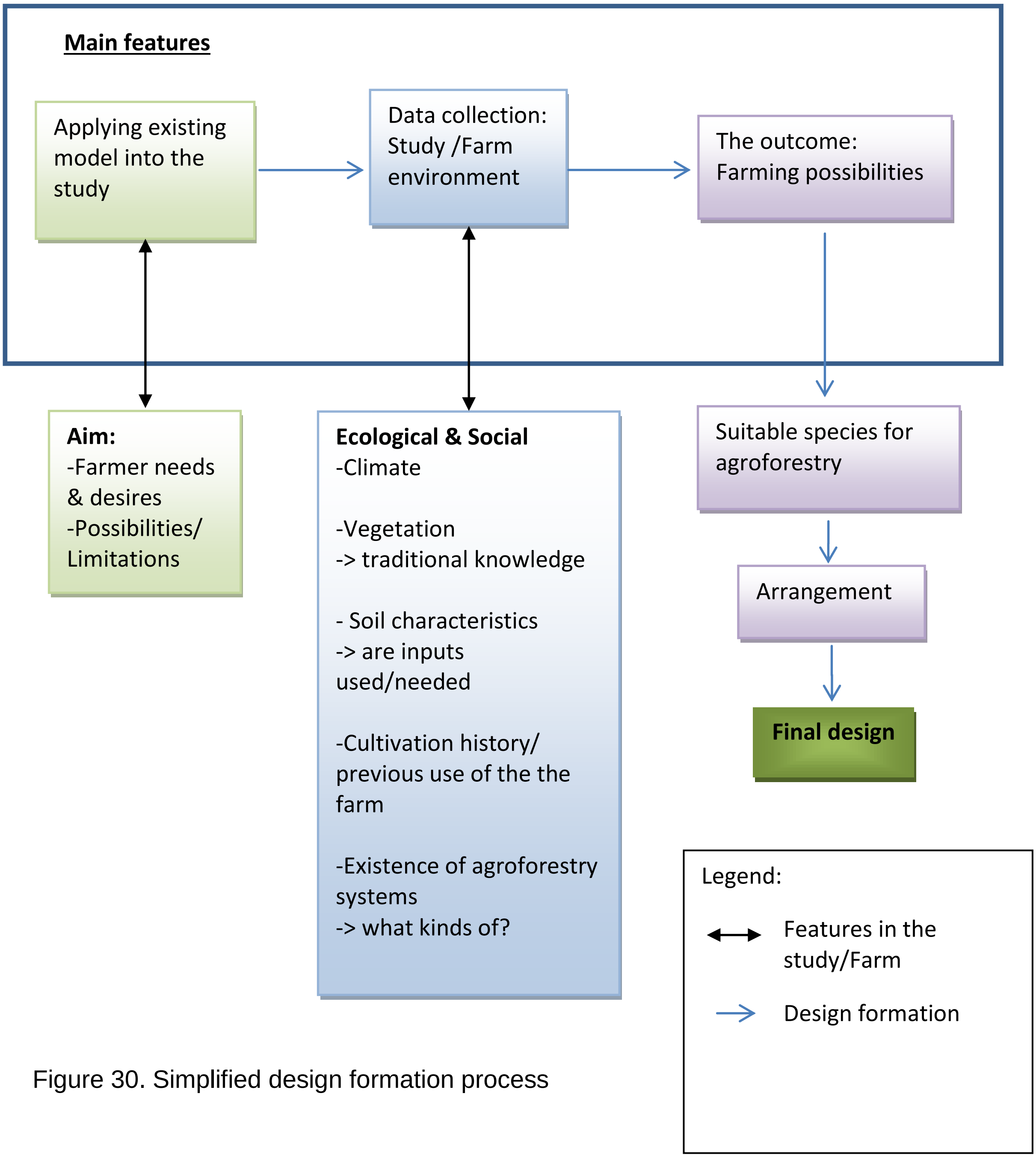

Figure 30. Simplified design formation process

kind of model is already available to be applied by a designer. The other main change is in the data collection part, in which ecological and social features are handled together and the idea is that the data collected is supporting directly each other. This kind of process would be easier and quicker to be applied by farmers themselves. The information of the cultivation conditions would of course be more limited and the certainty of successive system design weaker, but this could be used as a general, easily modified system design framework. The biggest challenge here is the selection of the existing model suitable for the process.

7 CONCLUSION

After the agroforestry system designing process, it is not surprising that there are so many agroecosystem analysis and design guidelines available; designing an agroecosystem that would meet the needs and desires of the farmer, in ecologically and socially sustainable way, is not simple. A successful design model would not need any help from outside because a farmer could apply it him- or herself. This was not achieved in this study.

It is still unclear if it is even possible to have the kind of an agroecosystem design model that could be used in many different farms and by many different people. The scientific base for successful agroecosystem is in ecological and social understanding related to the content. This knowledge is difficult to achieve without any detailed analysis of the area. For low income groups, inputs for agroecosystem design are usually not available. As mentioned in the discussion, one solution could be in gathering the agricultural knowledge only from locals. However, like the case study proved, the real condition of the soil is difficult to recognize without any scientific analysis.

The future in agroecosystem analyzing and designing guidelines should be more in practical level. Questions like: how to recognize the most important actors in agroecosystems, and how to analyze their functioning in a simple way, should be solved if possible.

Existing guidelines are good base for further development, but the study focus should meet the aim of the recommendations as well. For successful system design, it is essential to recognize the differences between the guidelines used for background and the aims of the study itself. If the aims do not meet each other, probably the results differ as well. This might have been one of the challenges for this study as well. All three guidelines used as base for this study, were aiming in different things. The combination of those might have caused some contradictions. In the other hand, understanding the variation of starting points and possible results, can expand the way of thinking and bring up some new ideas. However, the selection of a suitable design model should always be based on the final aims and on the environmental starting point of the focus area.

Combining different guidelines is time consuming process itself, so that is why there is still a need to work further on a simple agroforestry system guideline model. The study helped to recognize the problems and challenges in the agroforestry design process; therefore it is a good background study for further development. An agroecosystem design model is an important field to work on for the development of sufficient food supply in tropical countries and because of that the research is hoped to be continued.

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APPENDIX

Anex 1. Questionnaire forms

Interview of local farmers

The questionnaire is for collecting the data of existing cultivations near to the study farm. The aim is to find out the major species cultivated, the ecological and social conditions for cultivation and farms' potential for agroforestry. The data will be used as a background for designing the agroforestry system to Dzivaresekwa.

The main focus is in species composition and agricultural management. It is a semi-structured interview, so there can be more questions added or left out.

Date:

Interpreter:

Site:

GPS position:

<u>Agroecosystem:</u>

__ Field cropping: monoculture __ mixed __

__ Agroforestry: homegarden__ other__

__ Pasture or other grazing system

__ Orchard

__ Other

Size character of the farm:

__Garden/field

__Small holding

__Small farm

__Large farm

__Other

Hectares_______

Main crop species:

Main tree/woody species:

Others (medical plants, protected etc.):

Number of crops per year:

Average annual yield from the main cultivation?

If the cultivations do not include trees are there still some grown in the farm area?

Yes__ No__

If there are trees what is/are the purpose/s for those?

Main products from the farm:

Is there some kind of rotation used in the field?

__ In time: year__ season__

__ In space: system layers__ field sections__

Are mineral fertilizers used?

Yes__ No__

If yes, what are those?

Are organic fertilizers used?

Yes__ No__

If yes, what are those?

Are pesticides used?

Yes__ No__

If yes, what are those?

Are animals involved in the system and what is their role?

Farm mechanization:

__Hoe and spade

__Plough and animals

__Plough and tractors

__Something else

How is the water supply managed?

__Irrigation

__Rainfed

From where, the farm is getting its seeds?

Purchased inputs to the farm?

Socio-economic characteristics of the farm:

Cultivation target:

__Homestead use

__Marketing

__Community use

__Other

How many are working in the farm?

What is their position?

__Hired

__Family

__Other

Land ownership:

__Freehold

__Tenancy

__Communal

__State

Is it possible to sell the farm?

Yes__ No__

Limitations (to who, when etc.)?

What is the previous land use?

Where does the farm get its household energy?

__Firewood

__Charcoal

__Other

What are the biggest concerns for the farm?

List of species:

Arable plans (grains, pulses etc.):

Garden plans (vegetables, herbs etc.):

Forage crops for animals:

Shrubs:

Fruit trees:

Other trees:

Others (break crops, green manure, safety plans etc.):

Agroecological characteristics of the project farm

This part of the study will focus on the project farm in Dzivaresekwa. The aim is to collect data about the farms' characteristics for further design plan. The part contains quantitative and qualitative field work in the target farm.

Soil samples:

Sample plots are selected randomly. Each of the sample plots are recorded with GPS (global position system) device for later analyses.

The samples will be taken with a soil auger from the uppermost layer (0-20 cm depth). From each sample following parameters are determined in the laboratory:

- soil organic carbon content
- pH
- main nutrient content; N, P
- Exchangeable cations; Mg, Ca, K
- soil texture

Data collection by observation:

- Slope:
- Availability of water:
- Existing vegetation:
- Other important notes

  -Eg. Dump site description

Interview of the project farm managers

This part is collecting data from the project farm managers, for finding out the possibilities and desires of the farm's owners.

- Main focus in production:
- By-products desired:
- Possibilities to irrigation:
    - Desire to:
- Possibility to invest per year:
- Number of people working in the field:
- Education of the labour:
- Seed purchase:
- Other notes:

Anex 2. Species considered for the agroforestry system

Table 1. Species considered to be implemented in the agroforestry system. Yellow color stands for recommendation (Landon 1991, Nair 1989, ICRAF 2013a, ICRAF 2013b).

Tree species

Specie considered	Used in agroforestry systems and grown in similar climatic conditions	Suitable for biophysical and ecological conditions of the farm	Production of firewood or fruits	Possible to intercrop (with which plants if known)	Plus remarks - native specie * - found from the area **	Other remarks
A. auriculiformis	x	x	x (fw)	no; dense canopy		altitude might be limiting
A. erioloba	x		x (Fw)	no	*	
A.karroo	x	x	x(fw)	yes; deep root system	*	thorns, might be competitive on water and nutrients
A. Nigrescens				no data	*	
A. polyacantha ssp. polyacantha	x	x	x	no	**	
A. sieberiana	x	x	x	no	*	hedge tree
A. Senegal	x	x	x	millet, sesame, sorghum, groundnuts, watermelon	*	restores soil fertility, produces gum
A. Tortillis	x			yes; mungbean, sorghum	*	
Adansonia	x		x	no	*	

digitata						
Albizia amara	x	x	x	maize, cassava, papaya, mango, orange	*	erosion control
Amygdalus persicae; peach		x	x(fr)	no	**	
Anthocleista grandiflora				no	*	
Araucaria cunninghamii	x			no	*	
Azanza garckeana	x	x	x (both)	no	*	high precipitation might be limiting
Azadirachta indica	x	x	x (both)	yes; pearl millet	*	high altitude might be limiting
Berchemia discolour	x	x	x (both)	no	*	
Brachystegia spiciformis; msasa	x	x	x (fw)	no	*	
Bridelia micrantha	x	x	x(both)	banana, coffee	*	shade, extensive root system
Cajanus cajan	x	x	x (fw)	yes; can be mixed with cereals, oil seeds, pulses, cotton	**	crop as itself
Carica papaya	x	x	x(fr)	no data	**	
Casuarina	x	x	x (fw)	yes		used mainly

cunninghamina						in china
Cassia abbreviata	x	x	x(fw)	deep root system; no competition with crops	*	soil conservation
Citrus grapefruit; grape fruit		x	x(fr)	no data	**	
Citrus x limon; lemon	x	x	x(fr)	no data	**	
Colophospermum mopane	x	x	x (both)	no	*	high altitude might be limiting
Diasphyros mespiliformis	x		x (both)	no	*, **	
Dovyalis caffra	x	x	x (fr)	no	*	hedge tree, can be grown close each other
Eucalyptus albida		x	x (fw)	no		
E. camuldulnses	x			yes; maize		high, light canopy , intercropping 5x5m
E. grandis	x	x	x (fw)	with maize and sorghum	**	
E.resinifera; Red mahogany		x	x (fw)	no		
E. tereticornis	x	x	x (fw)	no		high altitude and acidity might limit
Erythrina abyssinica	X	X	x (fw)	Possible to intercrop with annual	*	prefers low pH, seedlings needs frost

				plants		protection
Faidherbia albida	X		X	yes; maize	*	drops leaves during rainy season
Ficus sur		x	x (both)	no		
Gliricidia sepium	X	X	X (fw)	no		high altitude might limit, hedge tree
Grevillea robusta	x	x	x (fw)	yes; banana, tomatoe etc.		deep root system, pioneer in disturbed sites
Julbernardia globiflor; mnondo		x		no	*	typical miombo specie
Khaya anthotheca				no	**	good timber, easy to grow
Leucaena leucocephala	x		x(fw)	yes; alley cropping with multiple crops	**	3-10m spacing
Lovoa swynnertonii	x	x	x(fw)	Grows high; do not shade too much	*	
Malus domestica; apple	x		x(fw)	no data		
Mangifera indica; mango	x	x	x(fr)	yes; when young, homegarden	**	
Moringa oleifera	x	x	x (fw)	yes; light shade		high altitude might limit, protects from intense sunlight
Morus alba;	x		x(fw)	no data	**	

mulberry						
Musa spp; banana	x	x	x(fr)		**	High N, K, sensitive to frost
Persea americana; avocado	x	x	x(fr)	no data	**	
Pinus patula	x	x	x(fw)	no	**	
Psidium guavaja; guava	x	x	x(fr)	yes; cereals and cowpea	**	
Pterocarpus angolensis	x	x		no	*	timber
Sclerocarya birrea ssp. caffra	x		x (fr)	no	*	
Sesbania rostrata	x	x	x(fw)	alley cropping	*	soil improver
Sesbania sesban	x	x	x(fw)	yes; alley cropping	**	
Strychnos spinosa; mutamba	x		x(both)	no		
Syzygium cordatum	x	x	x(both)	no		
Syzygium guineense	x	x	x(both)	no	*	
Tephrosia vogelii	x	x		yes; shade tree	*	
Terminalia sericea		x	x (fw)	no	*	
Toona ciliata	x		timber	no	**	used as

						firebreak
Trichilia emetica	x	x	x(fw)	no	*, **	
Uapaca kirkiana; muzhanje	x	x	x(both)	no	*	
Vitis vinifera; grape	x	x	x(fr)	yes; alley cropping	**	sensitive to frost during the growing season
Warburgia salutaris	x	x	x(fw)	yes; shade for banana, coffee		
Ziziphus mauritiana; musau	x	x(altitude, pH7<)	x(both)	no	**	high altitude might limit, pH 7 <, used as fence

<u>Crops</u>

Specie	Suitable for conditions	Desired by the farmer	Suitable for agroforestry (previous experience)	Found from Dzivaresekwa	Other remarks
Beans; *Phaseolus spp.*	x	x	x (intercropping with cereals)	x	sensitive to low pH, frost
Bonongwe; *Amaranthus muricatus*	x		x	x	
Cabbage; *Brassica oleracea*	x	x	x	x	pH range: 6-7.5
Carrots; *Daucus carota*	x	x	x (alley cropping)		
Cassava; *Manihot esculenta*	x	x	x (alley cropping/plots with *Cajanus cajan*)	x	nutrient needs low tolrance
Cauliflower; Brassica		x	x (alley		

oleracea			cropping)		
Comfrey; *Symphytum officinale*				x	
Covo; *Tronchuda portuguesa*	x	x	no data	x	Observed to grow with trees
Cowpea; *Vigna unguiculata*	x		x	x	
Garlic; *Allium sativum*	x		x	x	
Groundnut; *Arachis hypogaea*	x	x	x		
Lentils; *Lens culinaris*	x				
Maize; *Zea mays*	x	x	x (some experience with Faidherbia, Eucalyptses)	x	C4 crop, shading can be harmful, high N
Okra; *Abelmoschus esculentus*	x		x	x	
Onion; *Allium cepa*	x	x	x	x	pH 6-7
Pea; *Pisum sativum*	x	x	x	x	pH 5.5-6.5
Potato; *Solanum tuberosum*	x		x		high K, well aerated soils pH 4.5-6
Pumpkins; *Cucurbita spp.*	x		x	x	
Rape; *Brassica napus*	x	x	x	x	Observed to grow with trees
Sorghum; *Sorghum bicolor*	x	x	x	x	fine texture ok, high N, pH 5-8.5
Spinach; *Spinachia oleracea*	x	x		x	

Sugarcane; *Saccharum spp.*	x		x	x	fine/medium texture, high N, pH 4.5-8.5
Sweet potato; Ipomoea batatas	x		x	x	high K
Tomato; *Solanum lycopersicum*	x	x	x	x	medium texture, sensitive to frost
Tsunga; *Brassica juncea*	x	x	no data	x	Observed to grow with trees

Anex 3. Summary of the soil sample data

Table 1. Summary of plot data

PLOT MEANS	Sample ref.	Longitude (36S)	Lattitude	pH	Conductivity micromhos	Initial N (ppm)	After incubation N (ppm)	Net N-mineralisation, mg/kg 14 days	Available P (ppm)	Exchangeable cations meq equivalents/100g K	Ca	Mg	Org. Carbons %	Texture
	1	279176	8029400	7,33	225	13,75	68,50	54,75	11	0,21	38,59	13,60	3,65	CL/SaC
	2	279071	8029512	7,38	233	14,75	49,00	34,25	13	0,58	38,62	18,68	2,40	fSaC
	3	278962	8029617	7,45	513	8,75	40,75	32,00	55	2,03	36,98	12,48	1,30	fSaC
	4	279108	8029945	4,95		15,75	31,00	15,25	4	0,19	6,47	3,73	1,49	fSaCL
	5	279207	8030186	7,55	306	25,00	58,00	33,00	23	0,60	81,55	19,18	2,34	fSaC
	6	279328	8030097	6,75		6,75	35,50	28,75	7	0,32	12,85	21,87	1,41	fSaC
	7	279503	8030281	5,28		22,75	82,75	60,00	158	0,79	23,52	5,86	2,83	cSaCL
	8	279655	8030402	5,78		12,25	53,00	40,75	101	1,40	16,11	5,86	2,45	mSaCL
	9	279530	8030504	6,25		23,75	75,50	51,75	266	1,71	39,89	19,07	3,05	mSaCL
	10	279434	8030600	6,43		15,50	54,75	39,25	118	2,02	40,02	22,46	4,26	C
	11	279805	8030544	5,48		14,75	39,50	24,75	26	1,54	11,11	3,84	2,70	mSaL
	12	279683	8030617	4,70		10,00	47,25	37,25	66	1,09	14,41	6,34	3,05	fSaL/mSaCL
	13	279798	8030794	4,80		11,50	44,00	32,50	54	0,46	18,90	15,75	2,53	SaCL*
	14	279931	8030936	6,38		10,50	29,50	19,00	75	1,24	22,30	15,58	2,45	C
	15	280000	8031119	5,60		14,00	53,50	39,50	152	0,44	25,01	12,39	1,70	fSaL
	16	280132	8031088	7,85	338	11,25	53,00	41,75	11	0,24	80,30	14,54	1,73	fSaCL
	17	280192	8031280	4,80		11,50	34,50	23,00	12	0,65	3,38	2,09	1,93	fSaL
	18	280045	8031314	5,90		18,50	31,00	12,50	41	0,64	25,22	14,53	2,21	SaC*
	19	280286	8031472	6,00		23,75	54,50	30,75	49	0,45	32,81	13,57	3,88	CL
	20	280357	8031400	7,13	255	16,25	34,50	18,25	11	0,30	22,47	6,88	2,13	fSaCL
total mean				6,19	311,67	15,05	48,50	33,45	62,65	0,85	29,53	12,42	2,47	
							high		very high	high	high	very high		
medium level							30-40		15-30	0.3-0.5	5-10	0.1-0.2		
							~35		~22,5	~0,4	~7.5	~0.15		
max				7,9 (16D)	700 (3A)	58 (9C)	121 (9C)		290 (9A)	3,3 (10D)	86,72 (5A)	26,88 (6B)	5,79 (10D)	
min				4,3 (11B)	111 (11D,6C)	5 (many)	19 (14D)		3 (6D)	0,14 (4B)	1,48 (11C)	1,78 (7D)	0,98 (3B)	

*Variation in coarseness, the conclusion has been made by ignoring the coarseness.